i Title Page

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IS THE BEST RECOVERY DRINK ALREADY IN YOUR FRIDGE?

The Effect of Milk Post-Exercise on Subsequent Performance Among Female Gaelic Football Players Aged 16-18 Years

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ii Declaration

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iv List of Abbreviations

M - milk	**AAs** – amino acids	**CK** – creatine kinase
CE – carbohydrate-electrolyte drink	**BCAAs** – branched chain amino acids	**EIMD** - exercise-induced muscle damage
CM – chocolate milk	**Mb** – myoglobin	**TT** – time trial
W - water	**MPS** – muscle protein synthesis	**TTE** – time trial to exhaustion

v Contents

List of Tables

List of Figures

List of Tables

List of Figures

2.11 Appendices

Chapter 1: Literature Review

IS THE BEST RECOVERY DRINK ALREADY IN YOUR FRIDGE?

The Role of Milk in Post-Exercise Recovery

1.1 Abstract

An effective recovery strategy is integral for any athlete to ensure subsequent performance is not compromised and is particularly pertinent where recovery time is restrictive. Although a relatively novel strand of dairy research, the role of bovine milk and milk-based products as effective recovery options is gathering pace.

Emerging applications include roles in rehydration and muscle recovery, attributed to milk's natural nutritional composition which satisfies the key components of recovery. Milk contains a natural source of carbohydrate (lactose) to support glycogen resynthesis; complete protein and branched chain amino acids (BCAAs) for muscle protein synthesis (MPS); as well as being a source of fluid and electrolytes to support rehydration. From a practical perspective to the athlete, milk is considered a natural, convenient, accessible and inexpensive recovery option. Chocolate milk has also been highlighted in the literature as a popular recovery solution, attributed to a favourable 3.5: 1 carbohydrate to protein ratio.

Despite the growing literature reporting the effectiveness of milk as a recovery solution, there is a paucity of research into milk's recovery role for the adolescent athlete. Given the specific nutritional considerations needed to support this stage of rapid growth and development, research to investigate the potential role of milk as an effective post-exercise recovery drink amongst this cohort is warranted. Other considerations for future research include a focus on the competitive and recreational player rather than elite or trained athletes; inclusion of female participants to address the existing bias towards male participants; as well as investigation across a variety of popular sports.

1.2 Introduction

Although a relatively novel strand of dairy research, milk has been highlighted in the literature as an effective recovery option for athletes (Sousa,Teixeira & Soares, 2014; Roy, 2008). Milk's effectiveness is attributed to its natural nutritional composition which satisfies the key components of recovery nutrition (Roy, 2008). Milk provides the natural sugar lactose to support glycogen resynthesis; whey protein and BCAAs for effective MPS stimulation; and is a fluid and electrolyte source to assist with rehydration (Roy, 2008; The National Dairy Council [NDC]. Food for Health Ireland [NDC]. [FHI], 2015; Thomas, Erdman & Burke, 2016).

The inaugural investigation into milk as an effective rehydration beverage was conducted by Shirreffs, Watson and Maughan (2007) who observed that participants remained euhydrated during a 4 hour (h) recovery period following skimmed milk consumption compared to water or a commercially available carbohydrate-electrolyte (CE) drink. Similar studies have supported these results among adult participants (Seery, 2015); and active youths (Volterman, Obeid, Wilk & Timmons, 2014a). Milk's effectiveness as a rehydration drink is attributed to the provision of fluid and electrolytes; as well as its protein and energy content which delay the gastric emptying of milk, slowing down its entry into circulation and preventing diuresis stimulation (Shirreffs et al., 2007; Volterman et al., 2014a; Watson, Love, Maughan & Shirreffs, 2008; James, Clayton & Evans, 2011; Desbrow, Jansen, Barret, Leveritt & Irwin, 2014a; Seery, 2015).

The role of milk in muscle recovery and subsequent isokinetic performance has also been investigated, with a volume of 500 mL (Cockburn, Robson-Ansley, Hayes &

Stevenson, 2012) of semi-skimmed milk demonstrated post-exercise (Cockburn, Stevenson, Hayes, Robson-Ansley & Howatson, 2010) as an effective option for attenuating exercise-induced muscle damage [EIMD]. This series of studies also extended to show improvements in subsequent aspects of team-sport performance such as agility and sprinting among males (Cockburn, Bell & Stevenson, 2013) and females (Rankin, Stevenson & Cockburn, 2015). Milk's provision of essential amino acids [AA], as well as insulin-stimulating carbohydrate to promote MPS is attributed to its effectiveness (Roy, 2008; Devries & Philips, 2015).

Additionally, chocolate milk (CM) has also been highlighted as a popular recovery solution, attributed to a favourable 3.5:1 carbohydrate to protein ratio (Pritchett & Pritchett, 2012) and effective stimulation of MPS (Ferguson-Stegall et al., 2011; Lunn et al., 2012).

In relation to resistance training, the effectiveness of milk post-exercise, particularly whey protein supplementation, has been noted for the promotion of muscle mass accretion (Hartman et al., 2007; Wilkinson et al., 2007; Josse, Tang, Tarnopolsky, & Phillips, 2010; Josse & Phillips, 2012; Hulmi, Lockwood & Stout, 2010; Volek et al., 2013; Miller, Alexander & Perez, 2014) and body fat loss (Josse, Tang, Tarnpolsky, & Philips, 2010; Josse & Phillips, 2012; Miller, Alexander & Perez, 2014). However, this review will focus on the application of the milk in its liquid form and the recovery aspects pertinent to the endurance exerciser.

1.3 Key Considerations of Recovery Nutrition

The application of effective nutritional recovery strategies is a well-established priority for endurance athletes in order to attenuate decrements in subsequent performance (Desbrow et al., 2014b; Australian Institute of Sport [AIS], 2009; Mujika & Burke, 2010; Pritchett, Pritchett & Bishop, 2011); with aspects such the timing and composition of foods pertinent areas of consideration for optimal recovery (International Olympic Committee [IOC], 2011). As endurance exercise elicits depletion of energy stores and muscle protein catabolism (Kammer et al., 2009), optimal refuelling of muscle glycogen stores; muscle repair; and restoration of fluid balance are main considerations for post-exercise recovery (Thomas et al., 2016; Mujika & Burke, 2010; Pritchett et al., 2011).

Consuming carbohydrate as soon as possible following high-intensity and endurance-type exercise is necessary for effective replenishment of muscle glycogen stores (Betts & Williams, 2010; Pritchett et al., 2011). A quantity of 1.2g/kg/hr of carbohydrate as glucose or sucrose has been suggested by Spaccarotella and Andzel (2011a) immediately after exercise and each hour thereafter for 4-6 hours.

Muscle protein breakdown and MPS are both stimulated in response to exercise (Maughan & Sherriffs, 2012), with the eccentric nature of team sports promoting protein breakdown and decreasing synthesis which can result in muscle damage (Poortmans, Carpentier, Pereira-Lancha, & Lancha, 2012). Therefore, provision of AAs post-exercise is necessary to stimulate insulin-signalling and the critical mTOR pathway needed to achieve net protein synthesis (Kammer et al., 2009; Blomstrand, Eliasson, Karlsson, & Kohnke, 2006; Ferguson-Stegall et al., 2011; Lunn et al., 2012;

Cermak, Res, de Groot, Saris & Van Loon, 2012). Specifically, the consumption of 15-25g of animal protein such as eggs, meat and particularly milk/whey is advised for optimal MPS (Beelen, Burke, Gibala, & Van Loon, 2010; Poortmans et al., 2012; Colombani & Mettler, 2011; Pritchett et al., 2011; Philips, Baar & Lewis, 2011), with leucine recognised as a potent signalling AA of the mTOR pathway (Farnfield, Carey, Gran, Trenerry, & Cameron-Smith, 2009).

To address these aspects, co-ingestion of carbohydrate and protein is suggested post-exercise, with carbohydrate providing substrate to refuel glycogen and to stimulate insulin production which, in turn, stimulates AA uptake by muscles (AIS, 2014). An optimal ratio of 3:1 carbohydrate to protein for glycogen resynthesis; and 4:1 or 5:1 for MPS is recommended (Kreider et al., 2010; NDC. FHI, 2015) and consumption within 30 minutes post-exercise is preferable for effective glycogen replacement and MPS (The Irish Sports Council, 2009). Extrapolating these guidelines to quantity per bodyweight, 0.8g/kg/hr of carbohydrate with 0.2-0.4g/kg/hr of protein during recovery is recommended (Cermak & Van Loon, 2013; Betts & Williams, 2010; Beelen et al., 2010).

In addition to glycogen replacement and MPS, a third priority for the athlete is to restore fluid and electrolyte balance (Desbrow et al., 2014b; American College of Sports Medicine [ACSM], 2011; Sawka et al., 2007). Following exercise, it is recommended to ingest a fluid quantity of 150% of body weight lost (Maughan & Leiper, 1995) and to replace sodium lost through sweat (Spaccarotella & Andzel, 2011a) – with a concentration of 50-80 mmol/L sodium suggested for optimal hydration (AIS, 2009) in fluid or food form (Sharp, 2007).

1.4 Milk's Nutritional Composition – Addressing Key Considerations of Recovery

The effectiveness of bovine milk as a post-exercise recovery option has been attributed to its natural nutritional composition which assist in addressing the '3 R's' of post-exercise recovery – Refuelling of glycogen stores; Repair of muscles; and Rehydration (Fig. 1). Milk contains water, carbohydrate, protein, the electrolytes sodium and potassium; as well as being a source of essential vitamins and minerals such as calcium, iodine, phosphorus, vitamin B2 and vitamin B12 (Table I; Finglas, et al., 2015; Food Safety Authority of Ireland [FSAI], 2014; European Commission [EC], 2015).

Table I: The nutritional composition (g/100g) of commercially available bovine liquid milk including macronutrients, and vitamins and minerals reaching a 'source' or 'high source' (Finglas et al., 2015; FSAI, 2014).

Nutrient	Whole Milk	Semi-Skimmed Milk	Skimmed Milk	1% Fat Milk	Chocolate Milk (low-fat)
Energy (Kcal) *(KJ)*	**63** **265**	**46** **195**	**34** **144**	**41** **173**	**72** **305**
Water	**87.6**	**89.4**	**90.8**	**90.1**	**82.8**
Carbohydrate (g) *sugars (g)* *Lactose (g)* *Sucrose (g)* *Fructose (g)*	**4.6** **4.6** **4.6** **0** **0**	**4.7** **4.7** **4.7** **0** **0**	**4.8** **4.8** **4.8** **0** **0**	**4.8** **4.8** **4.8** **0** **0**	**11.7** **11.0** **9.2** **2.8** **1.7**
Protein (g)	**3.4**	**3.5**	**3.5**	**3.5**	**3.6**
Fat (g)	**3.6**	**1.7**	**0.3**	**1.0**	**1.5**
Calcium (mg)	**120**	**120**	**125**	**123**	**115**
Phosphorus (mg)	**96**	**94**	**96**	**95**	**107**
Potassium (mg)	**157**	**156**	**162**	**159**	**206**
Iodine (µg)	**31**	***30***	***30***	***30***	***Nutrient present in significant quantities but no reliability on the amount***
Riboflavin (mg)	**0.23**	**0.24**	**0.22**	**0.23**	**0.17**
Vitamin B12 (µg)	**0.9**	**0.9**	**0.8**	**0.9**	**0.1**

1.4.1 Carbohydrate – Lactose

Milk provides carbohydrate (4.8 g/100g – Finglas et al., 2015) in the form of the natural sugar lactose – a disaccharide comprising of glucose and galactose (Fox, Uniacke-Lowe, McSweeney & O'Mahony, 2015). Although it is recognised that high-glycemic index (GI) sugars are particularly advantageous to effectively refuel glycogen stores rapidly following intense exercise (AIS, 2014; Donaldson, Perry & Rose, 2011; Betts & Williams, 2010) lactose, a low GI sugar (University of Sydney, 2014), also assists glycogen resynthesis by stimulating insulin production and, in turn, glycogen synthase (Bouskila, Hirshman, Jensen, Goodyear & Sakamoto, 2008). Of note, the concentration of milk carbohydrate at 4.8% is within the range of most commercially available sports drinks (4-8%) – a range acknowledged to improve endurance performance as well as ensuring minimal gastric discomfort (Jeukendrup, 2010; Sawka et al., 2007).

1.4.2 Protein – Casein and Whey

Dairy protein comprises of casein (80%) and whey fractions (20%) (Fox et al., 2015; Bendtsen, Lorenzen, Bendsen, Rasmussen & Astrup, 2013), with this 4:1 ratio allowing for slow digestion and absorption and, in turn, sustained increase of AA concentration in the blood (Bos et al., 2003). Whey protein has received considerable focus in relation to performance nutrition, recognised as a valuable source of BCAAs which account for up to one-third of the total AA content (The NDC. FHI, 2015). Whey-derived BCAAs are particularly noted for their role in MPS (Salinas-García et al., 2014; Ra et al., 2013; Kainulainen, Hulmi & Kujala, 2013; Devries & Phillips, 2015), with greater MPS stimulation demonstrated compared to casein or soy protein (Tang, Moore, Kujbida, Tarnopolsky & Phillips, 2009; Pennings et al., 2011). Additionally, whey protein is particularly high in the rapidly-digested AA leucine which is acknowledged for its anti-catabolic properties, regulation of protein metabolism and promotion of MPS (European Milk Forum [EMF], 2014; Phillips, 2011; Devries & Phillips, 2015). Casein is also a complete protein, providing all of the essential AAs (Bendsten et al., 2013). However, in contrast to whey, which is considered a ‘fast’ protein, casein is a ‘slow’ protein as it coagulates in the stomach and is emptied at a slower rate, allowing for a more prolonged rise in levels of plasma AAs (Tipton et al., 2004; Bendsten et al., 2013). Given these unique properties, in addition to technological aspects such as ease of flavouring and ability to blend, dairy protein recovery powders have become convenient and popular options among athletes, with milk-derived bioactive peptides also being explored for the development of innovative post-exercise recovery products (The NDC. FHI, 2015).

1.4.3 Fluid & Electrolytes

Milk comprises of approximately 89.5% water (Table II; Finglas et al., 2015) and provides the electrolytes sodium, potassium, calcium, magnesium, chloride, phosphate and sulphate (Fox et al., 2015) – which are highlighted among the major electrolytes lost through sweat (Maughan, Watson & Shirreffs, 2015). Additionally, as milk is a source of protein, this is proposed to delay gastric emptying of milk and therefore enhance fluid absorption (EMF, 2014; James et al., 2011; James, Gingell & Evans, 2012; James et al., 2013; James, Mattin, Aldiss, Adebishi & Hobson, 2014; Hobson & James, 2015).

1.4.4 The Milk Matrix

The concept of the ‘milk matrix’ is an emerging area of dairy research which focuses on the interplay of the entire nutrient portfolio of the food and its synergistic effects - rather than theeffects of individual nutrients (EMF, 2014; Astrup, 2014). As alluded to, milk provides the disaccharide lactose; the proteins casein and whey consisting of various protein fractions; dairy fat of which comprises over 400 fatty acids (Fox et al., 2015; Parodi, 2004); as well as a myriad of enzymes and bioactive constituents (Fox et al., 2015). Additionally, milk is a source of several essential vitamins and minerals (Table I). To date, the mechanism for milk's effectiveness as a recovery drink has been attributed to the individual components of milk addressing specific aspects of recovery nutrition (Roy, 2008). However, given milk's unique and complex blend of nutrients, further research is warranted into the mechanistic effect , if any, of the 'milk matrix' on post-exercise recovery.

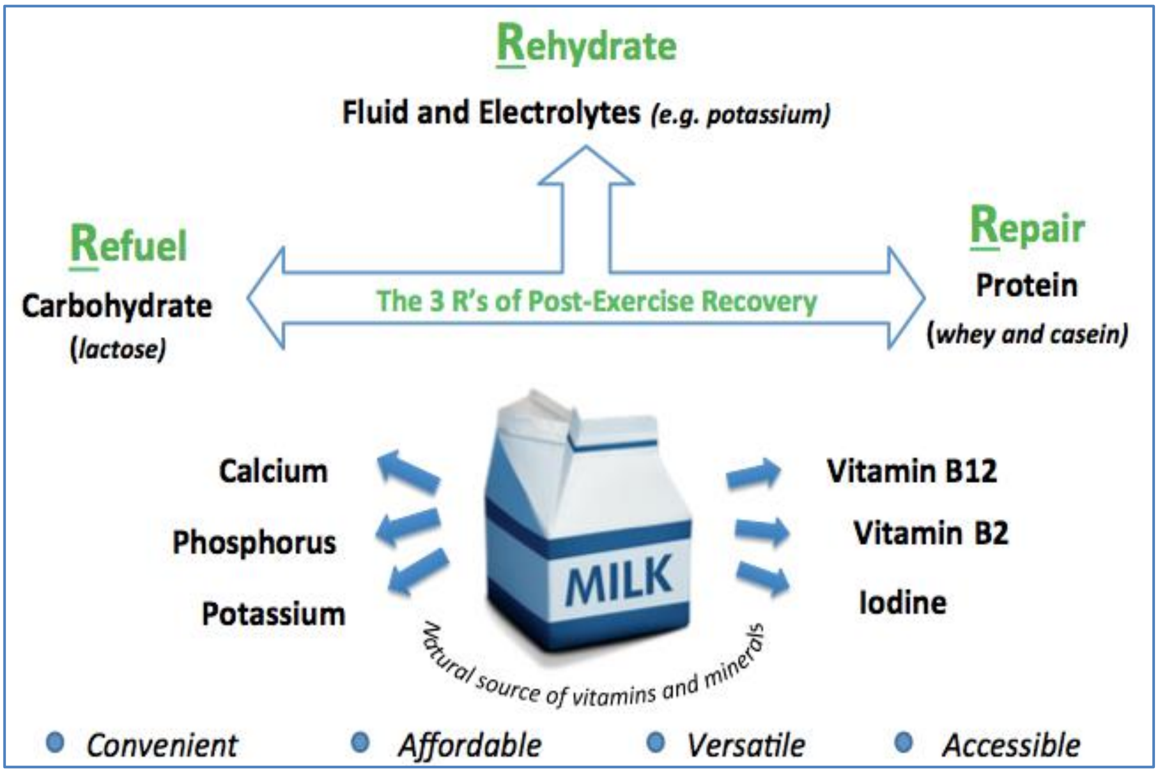

Figure. 1. The Attributes of Milk that Contribute to Post-Exercise Recovery and Health

1.5 Milk and Rehydration

Studies have demonstrated an ability of skimmed milk (M) to maintain hydration status equally, or better than, water (W) or a commercially available sports drink (CE) (Table II). The effectiveness of skimmed milk as a rehydration drink has been attributed to its fluid and electrolyte provision which are essential to address the restoration of fluid balance (Finglas et al., 2015; EMF, 2014; Sawka et al., 2007). Additionally, the protein and energy content of milk acts to slow the rate of gastric emptying by about 14% in comparison to CE (Shirreffs et al., 2007), facilitating greater intestinal water absorption and greater fluid retention by preventing diuresis stimulation (Shirreffs et al., 2007; Watson et al., 2008; James et al., 2011; Volterman et al., 2014a; Seery, 2015).

Table II: Summary of Randomised Controlled Trials (RCT) demonstrating the role of milk in rehydration after exercise

Reference	***Participants***		***Intervention***			***Results***	
	Gender	**Age (yrs)**	**Design**	**Protocol**	**Supplement**	**Total Urine Output (mL)**	**Finding**
Shirreffs et al. (2007)	11 (5 males; 6 females) healthy, recreationally active	24 ± 4	RCT Cross-over	Dehydration to 2% BW; Rehydration with test drink to 150% ; 4 h recovery	M (0.2% fat); CE; W; M+NaCl 4 isovolumetric measures every 15 mins	M: 611 ± 207 M + NaCl: 550 ml ± 141 CE: 1205 ± 142 W: 1184 ± 321	Significantly (p<0.001) lower urine output in M and M+NaCl than CE or W; no difference between M and M+NaCl
Watson et al. (2008)	7 males healthy, recreationally active	23 ± 3	RCT Cross-over	Dehydration to ~1.8% BW; Rehydration with test drink to 150%; 3 h recovery; <u>**TTE**</u>	M (0.1% fat); CE 4 isovolumetric measures every 15 mins	M: 525 ± 118 CE: 861 ± 396	The % of M retained was significantly (p=0.045) greater (77 ± 6%) than CE (62 ± 17%). No difference (p=0.952) in TTE at (39.7 ± 8.1 min) and (39.6 ± 7.3 min) for M and CE, respectively
Seery (2015)	7 males healthy, recreationally active	26.2 ± 6.1	RCT Cross-over	Dehydration to ~2% BW; Rehydration with test drink to 150%; 5 h recovery	M (0.1% fat); CE; W <u>**Metered**</u>**:** 1 L within 30 mins, 500 mL or remainder every 30 mins	M: 794 ± 99 CE:1314 ± 164 W: 1429 ± 131	Urine output was significantly (p=0.018) lower in M than W but not CE (P=0.057). An advantage of a metered approach to restoration of body fluid balance with M following exercise was demonstrated
Volterman et al. (2014a)	38 (19 males, 19 females) healthy, physically active	<u>**7-11**</u> (n=20) <u>**14-17**</u> (n=18)	RCT Cross-over	Dehydration to ~2% BW; Rehydration with test drink to <u>**100%**</u>; 2 h recovery	M (0% fat); CE; W 3 isovolumetric measures every 15 mins	M: 139.6 ± 105.2 CE: 309.7 ± 198.4 W: 315. ± 214.5	A significantly (p<0.001) higher percent of M was retained with M (74% ± 18%) compared with CE (59% ± 20%) or W (47% ± 26%). Skimmed milk was demonstrated as an effective rehydration option for the younger athlete
Desbrow et al. (2014)	15 males healthy, recreationally active	24.9 ± 5.5	RCT Cross-over	Dehydration to ~1.8% BW; Rehydration with test drink to 150%; 4 h recovery	<u>**CM (3.8%);**</u> CE; <u>**SM; MBS**</u> 4 isovolumetric measures every 15 mins	MBS: 771 ± 367 SM: 1143 ± 446 CM: 1338 ± 578 CE: 1833 ± 427	Milk-based drinks retained more fluid compared to CE (MBS: 65.1% ± 14.7%; CM: 40.0% ± 24.9%; SM: 46.9% ± 19.9%; and CE: 16.6% ± 16.5%)

The role of milk as an effective rehydration drink post-exercise was first investigated by Shirreffs et al. (2007) where skimmed milk (M) consumption post-exercise was compared to: W; CE; and M with additional 20 mmol/L of sodium chloride (NaCl) (Table II). Participants completed cycling bouts in a climate chamber (30-40˚C) until dehydration of 2% body mass was achieved. Following, participants consumed their assigned test drink, with the volumes equal to 150% of the volume of the body mass lost during exercise – a recommendation established as adequate to rehydrate post-exercise (Maughan, Leiper & Shirreffs, 1996) – provided in 4 isovolumetric measures every 15 minutes. Rehydration was then monitored via hourly urine output, with significantly ($p<0.001$) lower urine output observed in the M and M+ NaCl trials in comparison to water and CE; with no additional benefit of added NaCl to M observed (Table II). One hour into recovery, significantly less W and CE was retained compared to M, with participants remaining euhydrated in the M groups over the recovery duration.

This study marked the first of its kind in investigating the potential of M as a rehydration drink, although mechanisms are not explored. A robust and well-controlled study design was implemented, applying a cross-over design and relatively high number of participants (n=11) considering the demands and time dedication required. As the effects observed were following a 2% dehydration, an insight into the rehydrating potential of milk at various levels of dehydration is warranted. It is also noted that a mean ingestion of 1.79 L of fluid within an hour post-exercise may not be practical for an athlete to implement. Additionally, as the success of a post-exercise nutrition strategy is dependent on subsequent performance, a weakness of this study is that performance post-recovery was not investigated.

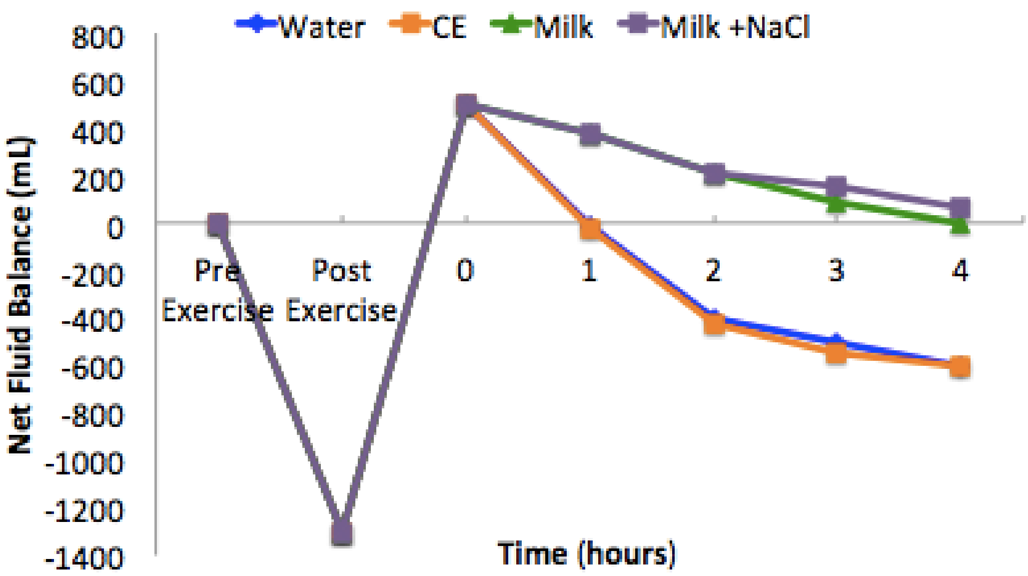

Figure. 2. Mean net fluid balance (mL). Adapted from Shirreffs et al. (2007).

To address the impact on subsequent performance, Watson et al., (2008) applied an almost identical protocol to Shirreffs et al. (2007), with participants consuming either M or CE and performing a time trial to exhaustion (TTE) following a 3 h recovery (Table II). At the end of recovery total urine volume was significantly lower in M than CE (Table II). However, no difference ($p=0.952$) in TTE was observed between M (39.7 ± 8.1 min) and CE (39.6 ± 7.3 min). This study possesses similar strengths to Shirreffs et al. (2007) in its study protocol and additionally addresses a research gap by investigating performance post-rehydration with milk. However, the sample size included in this study is quite small at 7 participants, and includes males only. Of note also is that a time trial (TT) rather than a TTE is a more relevant indicator of performance (Jeukendrup et al., 1996); with subsequent performance conducted in a hot, humid climate (35.2 ± 0.4◦C; 63 ± 2% relative humidity) - making it difficult to extrapolate similar effects to a more typical, temperate environment.

Seery (2015) recently replicated the earlier study of Shirreffs et al. (2007), with the adjustment to the protocol of applying a metered approach of M, CE and W ingestion (1 L within the first 30 minutes, followed by 500 mL - or remainder – every 30 minutes thereafter) adopted. This was chosen by the authors to avoid gastro-intestinal discomfort, as suggested by Shirreffs et al. (2007), when replacing 150% body mass loss within one hour; and to avoid over-stimulation of diuresis. Cumulative urine output following the 5 h recovery was lower in M compared to W but not CE (Table II). Compared to Shirreffs et al., (2007), which applied a similar study design (but did not implement this novel metered approach), ~ 5% greater net fluid retention was observed at 4 h by Seery (2015). This metered approach is advantageous as it appears to limit volume-induced diuresis as well as reflecting *ad libitum* drinking patterns, which is more realistic for an athlete to integrate into their rehydration strategy.

The rehydrating potential of milk among younger athletes was first investigated by Volterman et al. (2014a). Similar to Shirreffs et al. (2007) participants exercised in a climate chamber to a dehydration level of no more than 2%, consuming one of three test drinks: W; CE; or M post-exercise. However, rehydration over a 2 h recovery to 100% (rather than 150%) was applied for this younger cohort given the envisaged difficulty to consume such a large volume of fluid and in the absence of research into the optimal rehydration protocols for younger athletes. Results showed a lower urine output with M compared with CE or W (Table II). This is of note as commercially-available CE drinks are particularly popular among young people but are noted as providing excess caloric intakes and little nutritional value with adverse associations of weight gain and dental erosion (Committee on Nutrition and the Council on Sports Medicine and Fitness [CNCSMF], 2011). In contrast, milk is a nutrient-rich beverage providing calcium (Finglas et al., 2015) – a mineral which is essential for bone growth and development and maintenance of teeth (EC, 2015). As those aged 9-18 years have the highest calcium requirements (Institute of Medicine [IOM], 2011; Purcell et al., 2013) but are among those with the highest calcium insufficiencies of the population (Irish Universities Nutrition Alliance [IUNA], 2008), the rehydrating potential of milk among this cohort may be additionally beneficial from a public health perspective by identifying an appropriate consumption occasion to help address this nutrient shortfall.

In the literature reported thus far, skimmed milk at 0-0.2% has been applied as the comparison milk to other rehydration beverages. However, Desbrow et al. (2014) compared the rehydrating ability of 3.8% cow's milk (CM) with: soy milk (SM); a milk-based liquid supplement (MBS); and CE. Following a similar dehydrating and rehydrating protocol to Shirreffs et al. (2007), results supported a greater ability of milk-based beverages in enhancing fluid retention when compared to CE (Table II). Although the test beverages were not matched for energy and macronutrient content, a dose-response relationship was demonstrated in terms of total calorie, protein and sodium contents. This supports the mechanism proposed in the previously reported studies that energy and protein content can act to enhance rehydration by encouraging a slower gastric emptying. Furthermore, as similar fluid retention properties of the cow's milk and soy milk were observed, this infers that protein content - rather than the protein source - influences rehydration potential. This supports findings from a series of studies by James (James et al., 2011; James et al., 2012; James et al., 2013; James et al., 2014; Hobson & James, 2015) showing no increase in the rehydrating ability of a fluid replacement drink by addition of whey protein and suggests that the energy provision of the protein, rather than protein itself, infers the effectiveness of milk as rehydration beverage.

1.6 Milk and Exercise-Induced Muscle Damage (EIMD) Attenuation

The mechanism of EIMD was first described by Hough (1902), whereby delayed-onset muscle soreness (DOMS) results from small tears to the muscle fibres. Associated with this muscle damage is power and strength loss and impairments of neuromuscular and reflex actions – which can adversely affect performance (Etson, Byrne & Twist, 2003; Twist & Eston, 2005). Milk has been highlighted among a list of natural foods – including cherries, pomegranate and blueberries – that effectively address recovery from EIMD (Sousa et al., 2014). Specifically, 500 mL of semi-skimmed milk (Cockburn et al., 2012) has been demonstrated as an effective post-exercise (Cockburn et al., 2010) option to attenuate EIMD in males and females (Cockburn et al., 2008; Cockburn et al., 2013; Rankin et al., 2015) and has shown improvements in certain aspects of team sport performance (Cockburn et al., 2013) (Table III). The mechanism proposed the supply of protein and carbohydrate for effective MPS - a process stimulated by exercise - but requiring sufficient AAs for net protein accretion (Cermak et al., 2012); and carbohydrate to stimulate insulin release for efficient uptake of AAs into the muscle (AIS, 2014). In the absence of the provision of these nutrients, muscle protein breakdown would prevail - as this process is also stimulated by exercise). This would result in muscle damage as opposed to repair (Poortmans et al., 2012), thus compromising subsequent performance (Twist & Eston, 2005).

Table III: Summary of Randomised Controlled Trials (RCT) demonstrating the role of milk in the attenuation of EIMD

Reference	*Participants*		*Intervention*			*Results*	
	Gender	**Age (yrs)**	**Design**	**Protocol**	**Supplement**	**Performance**	**Finding**
Cockburn et al. (2008)	24 males team sport players	21 ± 3	RCT Independent Groups	Isokinetic muscle damage on hamstrings; test drink consumed; isokinetic performance (peak torque) at 24 h and 48 h post-exercise	1,000 mL : • CHO-P • CE • M (1.7% fat) • CON (water) 500 mL immediately and 2 h post-exercise	Peak torque (Nm) in the dominant leg was significantly ($p<0.05$) higher after 48 h in CHO-P (125 ± 14) compared with CON (86 ± 8) and CE (77 ± 18); and in M (113 ± 7) compared to CE (77 ± 18)	Milk-based drinks attenuated EIMD at 48 h following eccentric muscle damage
Cockburn et al. (2010)	32 males healthy	20 ± 2	RCT Independent Groups	Isokinetic muscle damage on hamstrings; performance – peak torque, reactive strength test – measures before, immediately after, at 48 h and 72 h post-exercise	1,000 mL CHO-P: • **PRE exercise** • **POST exercise** • **24 h POST exercise** • **CON at these time-points**	Likely benefit in POST group (-7% ± 30%) and 24 h POST group (-12 ± 25%) for peak torque in dominant leg between baseline and 48 h compared to PRE (-22% ± 14%) and CON (-24% ± 39%)	Milk-based CHO-P immediately or 24 h post muscle-damaging exercise may hasten recovery at 72 h
Cockburn et al. (2012)	24 males team sport players	21 ± 3	RCT Independent Groups	Isokinetic muscle damage on hamstrings; test drink post-exercise; performance e.g. peak torque test measures before, immediately after, at 48 h and 72 h post-exercise	• **500 mL** M (1.7% fat) • 1,000 mL M (1.7% fat) • 500 mL CON Consumption post-exercise	Results demonstrated no significant ($p=0.135$) difference at 72 h between consuming 500 mL or 1,000 mL of M for changes in peak torque (-3 ± 13%; -3 ± 14%, respectively)	500 mL of M was shown to have similar effects on EIMD attenuation as 1,000 mL
Cockburn et al. (2013)	14 males healthy	24 ± 4	RCT Independent Groups	Baseline tests **(CJH; reactive strength; agility; 15-m test) ;** isokinetic muscle damage on hamstrings; test drink consumed; baseline tests repeated at 24, 48 and 72h; **LIST** at 72 h	• 500 mL M (1.7% fat) • 500 mL CON Consumption post-exercise	Mean time for 15 m LIST sprint at 72 h significantly ($p=0.009$) less in M (0.0% ± 2.0%) compared to CON (2.4% ± 1.9%). At 72 h, likely benefit ($p= 0.086$) for agility time in M (0.7% ± 3.9%) compared with CON (4.8% ± 3.1%)	500 mL of M is effective at attenuating EIMD, demonstrating improvements in the team sport demands of agility and sprinting performance
Rankin et al. (2015)	32 (16 males; **16 females)** team sport players	23.7 ± 3.4	RCT Independent Groups	Baseline tests (CJH; peak torque; 20-m sprint; muscle soreness agility); isokinetic muscle damage on hamstrings; test drink; baseline tests repeated at 24, 48 and 72 h	• 500 mL M (1% fat) • 500 mL **isocaloric** CHO Consumption post-exercise	Significant ($p<0.05$) increase in female M compared to female CHO between baseline and 24 h peak torque (-5.3 ± 15.9%; -12.0 ± 11.4% respectively); likely benefit among females for 20 m sprint between baseline and 72 h (0.0 ± 3.0%; 2.7 ± 3.6 %, respectively)	500 mL M post muscle-damaging exercise can limit performance decrements in females and limit serum markers of muscle damage in males and females

Cockburn et al. (2008) examined the effects of an isovolumetric commercially-available skimmed milk-based carbohydrate-protein (CHO-P) beverage containing additional carbohydrate sources of sucrose, fructose, maltodextrin and cellulose; and milk (M) on EIMD following eccentric exercise, relative to water (CON) and CE (Table III). Muscle damage was induced in the hamstrings via isokinetic dynamometry with 500 mL of the allocated test drink consumed immediately after, and again within 2 h after exercise. Pre-exercise, 24 and 48 h post-exercise, subjective muscle soreness was recorded and blood samples were taken to measure blood protein markers of muscle damage – creatine kinase (CK) and myoglobin (Mb). At 24 and 48 h after exercise, isokinetic muscle performance was tested. Although no difference in muscle soreness was reported between groups, ($p>0.05$), peak torque was higher at 48 h in CHO-P and M compared to CE and CON (Table III); CK was lower at 48 h in CHO-P and M compared to CE with Mb lower in the CHO-P group compared with CE. The mechanism suggested by the authors is an alteration of protein metabolism via carbohydrate-protein co-ingestion to create an optimal MPS for alleviation of EIMD and, in turn, improve subsequent performance.

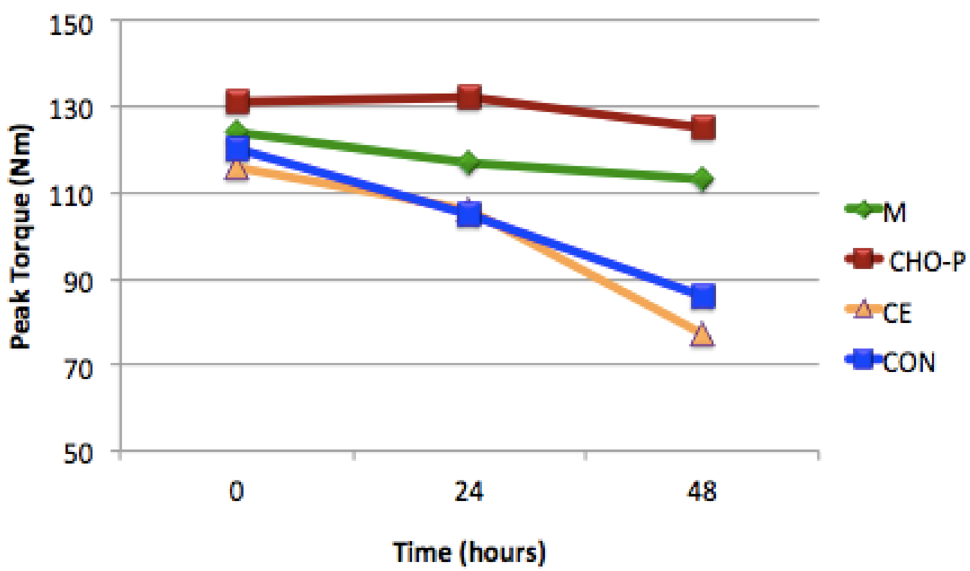

Figure. 3. Mean peak torque of dominant leg in response to EIMD at 0 h 24 h and 48 h. Adapted from Cockburn et al. (2008).

Cockburn et al. (2010) followed on to investigate the optimal timing of milk-based CHO-P for effective recovery. A volume of 1000 mL of CHO-P was consumed either before (PRE); immediately after (POST); at 24 h (24h POST); or water was consumed at these time points (CON). Similar markers of muscle damage to Cockburn et al. (2008) were assessed immediately before, at 24, 48 and 72 h following isokinetic muscle damage, with a beneficial effect of milk on peak torque in the dominant leg observed when consumed POST/24h POST (Table III). This study suggested that the activation of proteolytic pathways required for optimal MPS by consumption post-exercise enables athletes to train closer to peak levels 48 hours after muscle-damaging exercise. However, of note is that the large volume of 1,000 mL could result in gastric discomfort and unnecessary caloric intake (Cockburn et al., 2012) for the athlete and, therefore, may not be a practical recommendation to implement. Furthermore, as 20 g of protein ingestion is recognised as the threshold for optimal protein synthesis (Moore et al., 2009) , the 34 g of protein provided by 1,000 mL may not be of any further benefit, compared to a 17 g provision with 500 mL.

Subsequently, Cockburn et al. (2012) expanded their research by investigating if 500 mL of milk would result in a similar beneficial effect on EIMD attenuation as 1,000 mL (Cockburn et al., 2008; Cockburn et al., 2010). Three groups received either 500 mL or 1,000 mL of semi-skimmed milk; or 1,000 mL of water following EIMD. Results demonstrated no differences at 72 h between 500 mL or 1,000 mL of milk consumption for improved muscle performance (peak torque) (Table III), concluding 500 mL to be an adequate volume to attenuate EIMD.

Thus far in this series of studies, performance has been tested in a lab-based environment, making it difficult to determine any benefit for the team-sport athlete.

Cockburn et al. (2013) addressed this among male soccer players who received either 500 mL of M or water (CON) following isokinetic muscle damage. Prior and at 24, 48 and 72 post-exercise, indicators of team sport performance were measured (countermovement jump height (CJH), 15-m sprint, reactive strength and agility tests) and at 72 h participants also completed the Loughborough Intermittent Shuttle Test (LIST) – a validated tool designed to reflect the physiological demands of a soccer match (Nicholas, Nuttal & Williams, 2000). No benefit was shown for M compared with CON for muscle soreness, CK, Mb, CJH or reactive strength; although mean time to complete the 15 m LIST sprint at 72 h was less in the M group than CON when compared to pre-EIMD results (Table III).

Noted in the studies outlined above is the exclusive inclusion of male participants, with a need, therefore, for investigation into the female athlete – particularly considering contradictory studies investigating theeffects of EIMD among females exist in the literature (Sayers & Clarkson, 2001; Hubal, Rubinstein & Clarkson, 2008). Rankin et al. (2015) recently looked at the effect of milk post-exercise on the attenuation of EIMD across genders, with participants receiving 500 mL of M or an energy-matched carbohydrate-solution. This provision of isocaloric test drinks is a welcome modification to eliminate any performance enhancements observed from additional energy intakes (in contrast to the isovolumetric and large discrepancies in nutritional content in the previous studies on EIMD reported above). Results demonstrated an increase in female M compared to female CHO between baseline and 24 h for peak torque and 20 m sprint between baseline and 72 h (Table III).

Between gender differences were unclear from this study, but females demonstrated smaller increases in sprint times, muscle soreness and blood markers of muscle damage, with the protective effect of oestrogen in attenuating muscle damage post-exercise suggested for these outcomes (Markofski & Braun, 2014).

On reviewing these series of studies into EIMD, It is necessary to consider that muscle biopsies or magnetic resonance imaging (MRI) are the only methods of accurately assessing muscle damage, with muscle proteins in the blood such as CK and Mb considered qualitative indicators of damage with large variability (Clarkson & Hubal, 2002; Baird, Graham, Baker & Bickerstaff, 2012). For example, similar individuals subjected to a similar exercise protocol can show large discrepancies in CK, suggesting a genetic influence; while those who regularly participate in intense exercise have a raised base level of CK - making it difficult in its accuracy as a marker of muscle damage (Baird et al., 2012). However, due to the invasive techniques of muscle biopsies or MRI, these blood markers are commonly used across studies, which may not provide a conclusive depiction when considering the effects of milk on EIMD.

Although necessary to investigate a repeated bout effect, an independent group design was applied; which fails to discount any inter-individual variability within subjects - as a cross-over design would achieve (Elbourne et al., 2002). Additionally, given the free-living duration of these participants between laboratory visits, loss of control over dietary intake may have influenced results (Livingstone & Black, 2003). The application of a milk volume that is commercially available and easily consumed post-exercise offers ecological validity to these study findings. However, muscle damage via isokinetic dynamometry – particularly for the field-based athlete – does not reflect reality, with protocols implementing match play/typical training sessions to elicit muscle-damage warranted.

Thus far in the literature, the mechanistic effects of milk in relation to EIMD and subsequent performance improvements has been attributed to its nutritional composition, which provides favourable protein and carbohydrate contents to stimulate MPS . However, future studies are required to decipher the exact mechanisms at play, delving further into cellular and molecular responses, including the potential anti-inflammatory components of milk – as suggested by Cockburn et al. (2013) and Rankin et al. (2015). Such is based on the associated inflammation of skeletal muscle as a result of EIMD (Tidball, 2005; Schoenfeld, 2012; Walsh et al., 2011). Such anti-inflammatory components of dairy – namely whey and casein-derived peptides, conjugated linoleic acid [CLA] and lactoferrin – are recognised as having specific immunoregulatory effects to elicit an anti-inflammatory response and have been associated with the attenuation of chronic diseases such as cardiovascular disease and diabetes (NDC. FHI, 2013). Expansion of this research into this role in exercise recovery could offer clearer insights into the mechanistic effect of milk's attenuation of EIMD. However, as inflammatory processes post-exercise are noted as having a necessary role for long-term hypertrophic adaptations (Schoenfeld, 2012); it is worth investigating to what extent attenuation of EIMD intefers with musce adaptation and the overall consequences for an athlete.

Despite expansion of the research across genders and to recreational players, investigation into effects among younger athletes is warranted. Only one such study to date by Volterman et al. (2014b) has indicated a beneficial effect of skimmed milk consumption for enhancing whole body protein balance in children and adolescents post-exercise, with expansion to milk's ability for attenuating EIMD required. Such is of particular merit as this life-stage requires unique nutritional requirements during this rapid phase of growth and development (Food Safety Authority of Ireland, 2011). For example, this age group have the highest calcium requirements to support bone growth and development (IOM, 2011; Purcell et al., 2013), but have the highest insufficiencies of this mineral (IUNA, 2008). Therefore, research to identify an appropriate consumption occasion (post-exercise) of milk could help alleviate to this nutrient shortfall as well as benefitting post-exercise recovery.

1.7 Chocolate Milk and Endurance Recovery

Low-fat chocolate milk (CM) has been highlighted in the literature as a popular recovery option (Pritchett & Pritchett, 2012; Roy, 2008; Table IV). As with plain milk CM's effectiveness has been attributed to its nutritional composition consisting of a similar nutritional profile to low-fat milk in terms of fat, protein, vitamin and mineral content – but offering an additional 7g of carbohydrate content due to the added monosaccharide sugars glucose and sucrose (Table I; Finglas et al., 2015; Pritchett & Pritchett, 2012). CM's favourable 3.5:1 carbohydrate to protein ratio is particularly noted to effectively stimulate MPS, which is required for optimal muscle recovery (Ferguson-Stegall et al., 2011; Lunn et al., 2012). This additional carbohydrate content also satisfies the recommended 5:1 carbohydrate: protein ratio recommended for effective glycogen resynthesis (Kerksick et al., 2008) more closely than plain, low-fat milk (Table I).

Table IV: Summary of Randomised Controlled Trials (RCT) demonstrating the role of chocolate milk in post-exercise recovery

Reference	*Participants*		*Intervention*			*Results*	
	Population	**Age (yrs)**	**Design**	**Protocol**	**Supplement**	**Performance**	**Finding**
Karp et al. (2006)	9 males trained	22.1 ± 2	RCT Cross-over	Glycogen-depleting exercise; test drink; 4 h recovery; TTE (cycle)	Isovolumetric (509.1 ± 36.9 mL) CM; FR; CR Immediately and 2 h post-exercise	Significantly (p<0.05) greater TTE in CM (40.0 ± 14.7 mins) and FR (41.3 ± 15.0 mins) compared to CR (26.8 ± 10.3 mins),	CM may be considered an effective alternative to FR and CR for recovery from glycogen-depleting exercise
Thomas et al. (2009)	9 males trained	25.4 ± 8	RCT Cross-over	Glycogen-depleting exercise; test drink; 4 h recovery; TTE (cycle)	CM; CR; FR **Isocaloric CM and CR** Immediately and 2 h post-exercise	Significantly (p<0.05) greater TTE with CM (32 ± 11 mins) compared to FR (23 ± 8 mins) and CR (21 ± 8 mins)	Using isocaloric test drinks, results from Karp et al. (2006) are supported and performance enhancement due to additional caloric provision dismissed
Pritchett et al. (2009)	10 males trained	27.1 ± 7.9	RCT Cross-over	Glycogen-depleting exercise; test drink; 15-18 h recovery; TTE (cycle)	CM; Isocaloric CRB Immediately and 2 h post-exercise	No significant (p= 0.91) difference for TTE (CM 13 ± 10.2 mins; CRB 13.5 ± 8.9 mins). CK significantly (p<0.05) greater in CRB (211.9 ± 192.5U.L-1) compared to CM (27.9 ± 134.8.L-1)	CM was shown to be as effective as a commercially-available recovery beverage
Gilson et al. (2010)	13 males Division I soccer players	19.5 ± 3	RCT Cross-over	**1 week baseline training (BT); 4 days intense training (IT); test drink consumption after each IT session; performance (agility, vertical jump height, CK, MB, muscle soreness and fatigue) recorded on day 2 and day 4 of IT**	CM; Isocaloric, isovolumetric CR	No specific performance test performed. Similar effects for recovery indicators in CR and CM but levels of serum CK significantly (p ≤ 0.05) lower in CM (316.9 ± 188.3 U.L-1), compared to CR (431.6 ± 310.8 U.L-1)	Similar muscle recovery between CM and CR demonstrated
Spacarrotella & Andzel (2011b)	13 (5 males; 8 f**emales**) Division III soccer players	19.5 ± 1.1	RCT Cross-over	Morning training session; test drink consumed; afternoon training session; TTE (20 m shuttle run)	CM; Isovolumetric (240 mL) CE Immediately and 2 h post-exercise	No significant (p> 0.05) difference in TTE between CM (6.11 ± 5.12 mins) compared with CE (5.03 ± 3.41 mins). Among males, a trend (p=0.03) of increased TTE with CM (8.31 ± 6.53 mins) compared with CE (6.24 ± 5.03 mins)	CM may be as effective as CE for recovery between team-sport training sessions

Table IV (*continued*): Summary of Randomised Controlled Trials (RCT) demonstrating the role of chocolate milk in post-exercise recovery

Reference	***Participants***		***Intervention***			***Results***	
	Population	**Age (yrs)**	**Design**	**Protocol**	**Supplement**	**Performance , Glycogen Resynthesis and MPS**	**Finding**
Ferguson-Stegall et al. (2011)	10 (5 males; 5 females) highly trained	31.8 ± 5.6	RCT Cross-over	Glycogen-depleting exercise; test drink; 4 h recovery; TT (40km cycle)	CM; Isocaloric CHO; PLA Immediately and 2 h post-exercise Volume stratified according to body weight	Significantly (p≤ 0.05) faster TT in CM (79.43 ± 2.11 mins) than CHO (85.74 ± 3.44 mins) and PLA (86.92 ± 3.28 mins). Significantly (p≤ 0.05) greater **glycogen resynthesis** in CM (23.58 µmol.g-1) and CHO (30.58 µmol.g-1) compared to PLA (7.05 µmol.g-1) Rapamycin phosphorylation – a **MPS regulator** – significantly (p≤ 0.05) greater 45 minutes into recovery in CM (174.4 ± 36.3%) compared to CHO (131.3 ± 28.1%) and PLA (73.7 ± 7.8%)	CM is more effective than isocaloric CHO or PLA at TT improvement in trained athletes. Proposed mechanism of effect for CM's effectiveness is stimulation of protein synthesis by activating key signalling proteins
Lunn et al. (2012)	*STUDY A:* 8 males **recreational runners** *STUDY B:* 6 males **recreational runners**	*STUDY A:* 23.7 ± 1.6 *STUDY B:* 21.3 ± 1.2	STUDY A: RCT Cross-over STUDY B: RCT Cross-over	*STUDY A:* 45 min run at 65% $\dot{V}O_2max$; test drink; 3 h recovery with muscle biopsies at regular intervals *STUDY B:* 45 min run at 65% $\dot{V}O_2max$; test drink; 3 h recovery ; TTE (treadmill run) **Eucaloric diet provided throughout study durations**	CM; Isocaloric, non-nitrogenous CR Immediately post-exercise	TTE was significantly (p=0.03) 23% greater with CM (250 ± 43 seconds) compared with CR (203 ± 31 seconds) No difference in glycogen resynthesis (protocol was not sufficient to deplete glycogen) capase-3 – a measure of proteolytic activity – significantly (P<0.05) lower at the end of recovery for CM (-2.06 ± 0.45) compared with CR (1.10 ± 0.13)	Elevated measures of skeletal muscle protein synthesis and suppressed whole-body protein breakdown after consuming CM, compared to CR. Proposed mechanism of effect by Ferguson-Stegall et al. (2011) supported

The inaugural study investigating CM as a recovery drink by Karp et al., (2006) compared isovolumetric drinks – CM; a carbohydrate replacement drink [CR]; and a fluid replacement drink [FR] – with participants consuming immediately and 2 h after a glycogen-depleting exercise bout. Following a 4 h recovery, participants completed a cycle TTE with results showing a significantly ($p<0.05$) greater TTE with CM and FR compared to CR, but with no difference demonstrated between CM and FR (Table IV). However, as CM and CR drinks were isovolumetric and not isocaloric, an improved TTE as a result of calorie provision could not be discounted – although as CM and CR had similar carbohydrate content (70.0 ± 4.9g) compared to FR (29.7 ± 2.1g) the lower carbohydrate content of FR did not offer any disadvantage in performance compared to CM, suggesting that something other than carbohydrate provision assisted in muscle glycogen replenishment. The authors suggested that the variations in carbohydrate type affected the digestion of the test drinks and resulted in the amelioration of performance observed.

Implementing an identical study protocol, but matching CM and CR for energy content, Thomas, Morris & Stevenson (2009) echoed the findings of Karp et al., (2006), with TTE greater for CM compared to FR and CR (Table IV). With this design dismissing enhanced performance observed as a result of additional caloric provision, the authors propose the additional carbohydrate provision of CM in assisting glycogen replenishment and/or that the fat content provided fatty acids as fuel and, in turn, delaying depletion of glycogen. Of note, the ecological validity of these two studies is quite weak with elite participants included - making extrapolation to competitive athletes or recreational exercisers difficult. Although implemented to ensure optimal control over dietary intake and physical activity participation, a 4 h recovery time is also not typical before subsequent performance would be expected, unless in a tournament situation for example. Additionally, TTE is not considered reflective of sporting demands, with a TT considered more insightful when investigating the effectiveness of a nutritional intervention on performance (Jeukendrup et al., 1996).

A progression of the research by Pritchett, Bishop, Pritchett, Green, and Katica (2009) compared the effect of CM with a commercially-available recovery beverage (CRB). Immediately following glycogen depleting exercise and 2 h after into a 15-18 h recovery, either isocaloric CM or CRB was consumed. Participants then completed a TTE which showed no difference between trials; however, CK was greater in CRB compared to CM (Table IV). Welcome is the longer recovery time of 15-18 h which is somewhat more reflective of sporting demands. However, as alluded to, CK as a marker of muscle damage is questioned as an accurate depiction of muscle damage (Baird et al., 2012; Clarkson & Hubal, 2002). Also questioned, as stated, is a TTE as a reflection of sporting demands (Jeukendrup et al., 1996). Of note, participants in the studies reported above involved trained cyclists, with research into the role of CM as part of an effective recovery strategy for team sport athletes – as well as chronic rather than acute effects – warranted.

In addressing these aspects, Gilson et al. (2010) investigated the effect of chronic CM consumption among male soccer players who participated in one week of off-season training (baseline training [BT]) followed by four consecutive days of intense training (IT). Following IT sessions, either CR or isocaloric, isovolumetric CM was consumed.

Levels of CK were lower in CM compared to CR (Table IV), although no specific test was conducted to measure performance. Although a number of limitations were highlighted by the authors – such as omission of a control drink and specific performance tests – this study was the first of its kind to explore a more realistic method of glycogen-depletion via on-field training as opposed to lab-based methods.

With the literature thus far biased towards male athletes, Spacarrotella & Andzel (2011b) expanded the research to include male and female soccer players, with a 20-metre shuttle run to fatigue (TTE) measuring performance. After a morning training session, participants consumed CM or CE immediately after and, again, 2 h later, followed by another afternoon practice. The TTE was then performed, with no difference observed between CM and CE (Table IV). The authors noted a trend ($p=0.03$) among the male participants of increased TTE with CM (8.31 ± 6.53 mins; median 4.34 mins) compared with CE (6.24 ± 5.03 mins; median 4.06 mins) and, although no significance shown, it could be postulated that this marginal attenuation of fatigue could be particularly advantageous towards the end of a competitive match (Rampinini et al., 2011). However, repetition of this study with a larger sample size may be needed to establish the true significance and any relevance of this trend. Additionally, regarding the study design, it is not common practice for non-elite players to participate in two training sessions in one day, followed by a run to fatigue (Casamichana, Castellano, Calleja-Gonzalez, San Román & Castagna, 2013) - with protocols more reflective of sporting demands required.

Despite the literature accumulating, none of the studies reported above investigated the exact mechanisms responsible for CM's effectiveness as a recovery option. Ferguson-Stegall et al. (2011) addressed this by looking at CM's effect on glycogen resynthesis and MPS where CM, isocaloric CHO or a placebo (PLA) was consumed immediately after glycogen-depleting exercise and 2 h into a 4 h recovery. To assess recovery via subsequent performance, participants completed a 40-kilometer cycling TT, with CM demonstrating a faster TT than CHO and PLA (Table IV). Glycogen resynthesis was also higher in CM and CHO compared to PLA, with no difference between CM and CHO (Table IV). This finding dismissed the mechanism of improved muscle glycogen resynthesis; however, markers of MPS signalling demonstrated favourable results. For example, rapamycin phosphorylation – a regulator of MPS – was greater 45 mins into recovery in CM compared to CHO and PLA (Table IV). Delayed gastric emptying associated with CM intake (Okabe, Terashima & Sakamoto, 2015) is proposed to have facilitated movement of carbohydrate and AA into the muscle for MPS stimulation. Efficient MPS is needed for net protein accretion and muscle adaptation (Cermak et al., 2012) which can attenuate muscle damage (Poortmans et al., 2012) and, in turn, ameliorate subsequent performance (Twist & Eston, 2005). The inclusion of trained athletes in this makes findings difficult to extrapolate to the competitive/recreational participant (Kusy & Zieliński, 2014); although welcome is the inclusion of a TT rather than a TTE, which is considered more reflective of sporting demands (Jeukendrup et al., 1996).

A further study into the mechanisms of effect was conducted by Lunn et al. (2012), focusing on CM consumption in comparison to an isocaloric, non-nitrogenous CR drink.

The first trial involved a 45-minutes run, consumption of the assigned drink, followed by a 3 h recovery where muscle biopsies were taken at regular intervals. The second trial involved a similar protocol, but a TTE following a 3 h recovery and no muscle biopsy measures taken. Similar to Ferguson-Stegall et al. (2011), no difference in muscle glycogen resynthesis was shown, although TTE was greater with CM compared with CR (Table IV). MPS was also increased in the CM group; for example, capase-3 – a measure of proteolytic activity – was lower at the end of recovery for CM compared with CR (Table IV). These findings support the mechanism proposed by Ferguson-Stegall et al. (2011), suggesting the insulin response from carbohydrate ingestion; as well AA provision for effective MPS stimulation improved performance by facilitating muscle adaptation to exercise. However, further research into these mechanisms is suggested and warranted. A rare and welcome aspect of this study noted was the provision of a eucaloric diet to participants for the entire study duration to ensure the confounding factor of dietary intake was tightly controlled.

1.8 Conclusion

Although a relatively novel strand of dairy research, the literature on the beneficial effects of milk and milk-based products in the application of post-exercise recovery is accumulating. Specific roles in glycogen resynthesis, attenuation of EIMD and effective rehydration have been explored, with milk's effectiveness attributed to its natural nutritional composition. From a practical perspective to the athlete, milk is a convenient, accessible and natural recovery option, as well as being a low-cost alternative to commercially-available powder and liquid supplements.

Skimmed milk (0-0.2%) has been demonstrated as a more effective rehydration option compared to water or a carbohydrate-electrolyte drink among adult and youth athletes (Shirreffs et al., 2007; Volterman et al., 2014a). The proposed mechanism for the greater fluid absorption observed with milk has been consistent across studies, attributed to milk's protein and energy contents which act to delay gastric emptying – slowing down its entry into circulation and, in turn, preventing diuresis stimulation (Shirreffs et al., 2007; Seery, 2015; Volterman et al., 2014a; Watson et al., 2008; James, et al., 2011). However, the research designs used to investigate milk's rehydration potential have been lab-based, requiring exercising in a heat chamber, drinking a volume of test beverages in accordance with fluid losses and participating in a TTE to assess subsequent performance. Further studies which adopt a research protocol more conducive to the demands and practices of various sports are needed. Suggested is the inclusion of larger participant numbers; further investigation into the exact mechanisms at play; as well as effects on subsequent performance via reflective methods of the sporting demands to determine the exact benefits to the athlete of including skimmed milk as part of their recovery strategy.

Additionally, CM has been highlighted as a popular recovery option following endurance exercise, demonstrating similar effects on subsequent performance to CE (Spaccarotella & Andel, 2011b) and CRB (Pritchett et al., 2009), with a superior performance to CR observed (Karp et al., 2006; Thomas et al., 2009; Lunn et al., 2012). Research shows applications across sports that require short recovery times of 2-3 hours (Karp et al., 2006; Thomas et al., 2009; Spaccarotella & Andel, 2011b; Lunn et al., 2012); and for team sports which demand performance over subsequent days (Gilson et al., 2010). Effective stimulation of MPS due to a favourable 3.5:1 carbohydrate to protein ratio is the proposed mechanism for milk's effectiveness (Ferguson-Stegall et al., 2011; Lunn et al., 2012); although further research is needed to determine exact mechanisms at play. A prescriptive 1.0-1.5g/kg-1hr-1 of CM has been recommended post-exercise and 2 h thereafter by Pritchett and Pritchett (2012). However, further research is also required to decipher optimal volume, timing, and consumption frequency when considering recommendations: for elite athletes and recreational exercisers; across various sports and exercise programs; among males and females; and the variable effects of acute versus chronic supplementation.

Regarding muscle recovery and subsequent performance, a volume of 500 mL (Cockburn et al., 2012) of semi-skimmed milk has been demonstrated post-exercise (Cockburn et al., 2010) as more effective in attenuating EIMD in comparison to water or CE. Research also extended to show improvements in subsequent performance among males (Cockburn et al., 2013) and females (Rankin et al., 2015). Mechanisms proposed again revert to the nutritional composition of milk, with the provision of essential AAs, particularly leucine, and BCAAs which are recognised for effective MPS (Roy, 2008; NDC. FHI, 2015; Salinas-García et al., 2014; Ra et al., 2013; Kainulainen et al., 2013; Devries & Phillips, 2015 ; Phillips & Van Loon, 2011). Future studies are needed to determine other potential mechanisms at play, such as milk's potential anti-inflammmatory role in alleviating EIMD or the emerging 'dairy matrix' research looking at the interplay of nutrients rather than in isolation (EMF, 2014; Praagman et al., 2016).

Despite this progressive series of research focussing on various aspects of milk's role in attenuating EIMD and improving subsequent performance, no study published to date has expanded these investigations to the younger athlete. Establishing a similar role for milk – a convenient, natural and calcium-rich beverage (EMF, 2014) among this younger cohort could be particularly relevant given their: higher calcium requirements (IOM, 2011; Purcell et al., 2013; Department of Health/Health Service Executive, 2012); high prevalence of calcium insufficiencies (IUNA, 2008); and the recommendation to refrain from the use of recovery supplements (Thomas et al., 2016; Desbrow et al., 2013b; Irish Rugby Football Union, 2013;). Other participant considerations for future research include a focus on the competitive player rather than trained/elite athlete; a focus on female subjects given the existing bias towards male participants in sports science research (Costello, Bieuzen & Bleakley, 2014) and studies investigating post-exercise nutritional strategies (Pritchett et al., 2011); as well as the expansion of research across a variety of popular sports.

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2. Research Project

IS THE BEST RECOVERY DRINK ALREADY IN YOUR FRIDGE?

"The effect of milk post-exercise on subsequent performance among female Gaelic football players aged 16-18 years"

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2.1 Journal Selection

Detailed below is a collection of studies investigating the effectiveness of milk or a carbohydrate-protein supplement to attenuate muscle damage and/or effects on subsequent performance. ***The Journal of Sports Sciences*** was chosen as this Journal places emphasis on the ''human sciences applied to sport and exercise'' and includes studies on research into training and performance prediction.

Given the similar focus on performance prediction in a recent paper affiliated with the University of Chester and published by this Journal (Highton, Twist, Lamb & Nicholas, 2013); as well as the absence of depth into mechanisms of physiology and metabolism in this current study, the other Journals below were discounted:

Table I: Justification of Journal Selection

Journal of Sports Sciences	**Highton, Twist, Lamb and Nicholas (2013)**
Medicine and Science in Sports and Exercise	Cockburn, Bell and Stevenson (2013); Lunn et al. (2012)
Applied Physiology and Nutrition Metabolism	Cockburn, Hayes, French, Stevenson and St Clair Gibson (2008); Cockburn, Stevenson, Hayes, Robson-Ansley and Howatson (2010); Thomas, Morris and Stevenson (2009); Pritchett, Bishop, Pritchett, Green and Katica (2009)
European Journal of Applied Physiology	Cockburn, Robson-Ansley, Hayes, and Stevenson (2012); Rankin, Stevenson and Cockburn (2015)
The Journal of Strength & Conditioning Research	Ferguson-Stegall et al.(2011); Spaccarotella and Andzel (2011)
Journal of the International Society of Sports Nutrition	Gilson et al. (2012); Roy (2008)
Medicine and Sports Science	Pritchett and Pritchett (2012)
International Journal of Sports Nutrition and Exercise Metabolism	Karp et al. (2006)

2.2 Abstract

Background: The beneficial role of milk and milk-based products in the area of recovery nutrition has been reported in the literature; with milk's natural nutritional composition addressing the main priorities of recovery suggested as the mechanism for its effectiveness. However, no studies exist to date investigating this potential benefit among female, adolescent athletes.

Objective: To investigate the effectiveness of milk post-exercise on subsequent performance among female Gaelic football players aged 16-18 years.

Methods: In this randomised, counter-balanced, cross-over study, ten participants (age 16.5 ± 0.6 years; height 166.4 ± 6.9 cm, body weight 58.2 ± 9.2 kg) completed two trials consisting of a typical training session, consumption of a test drink (500 mL of milk [M] or 500 mL of water [CON]) followed by a 2 hour (2-h) recovery, after which performance indicators were measured: countermovement jump height [CJH]; drop jump [DJ]; and 20 metre sprint [20-m].

Results: No significant ($p>0.05$) difference was observed between M and CON for: CJH (35.7 ± 8.5 cm; 34.9 ± 5.3 cm, respectively; $p=0.603$); or DJ (36.4 ± 7.9 cm; 36.4 ± 5.1 cm, respectively; $p=0.971$). A significant ($p=0.02$) difference for 20-m sprint speed was reported between M (3.85 ± 0.35 s) and CON (4.02 ± 0.32 s).

Conclusion: This study demonstrates a role for milk – a natural, accessible, affordable and calcium-rich beverage – post-exercise among female Gaelic football players aged 16-18 years for improving subsequent sprint performance. This is of particular

relevance for this cohort who has the highest calcium requirements and, concurrently, the highest calcium insufficiencies of the Irish population. Future studies should include larger sample sizes with expansion to explore potential roles among male adolescents and across a variety of sports and competitive levels.

500 mL of milk post-exercise improves subsequent sprint performance among female, adolescent, team-sport players.

Key words: Milk, Gaelic Football, Adolescent, Recovery

2.3 Introduction

An effective recovery strategy is integral for athletes to ensure subsequent performance is not compromised; and is particularly pertinent where recovery time is restrictive (Mujika & Burke, 2010; Beelen, Burke, Gibala & Van Loon, 2010; Pritchett, Pritchett & Bishop, 2011; Australian Institute of Sport [AIS], 2009).

Bovine milk has been highlighted as an effective recovery option post-exercise (Sousa, Teixeira & Soares, 2014), with this effectiveness attributed to its natural nutritional composition which help to address the key components of recovery (Roy, 2008).

Milk provides a natural source of carbohydrate (lactose) to support glycogen resynthesis; whey protein and branched chain amino acids [BCAAs] – particularly leucine - for muscle protein synthesis (MPS) and muscle adaptation; as well as fluid and electrolytes to support rehydration (Roy, 2008; Devries & Phillips, 2015; Thomas, Erdman & Burke, 2016). From a practical perspective to the athlete, milk is considered a convenient, accessible and natural recovery option; as well as being a low-cost alternative to commercially-available recovery supplements (The National Dairy Council. Food for Health Ireland [NDC.FHI], 2015a).

The accumulating literature in this area specifically demonstrates milk's application for effective: restoration of fluid balance (Shirreffs, Watson & Maughan, 2007; Seery, 2015; Volterman, Obeid, Wilk & Timmons, 2014a); the attenuation of exercise-induced muscle damage [EIMD] (Cockburn, Hayes, French, Stevenson & St Clair Gibson, 2008; Rankin, Stevenson & Cockburn, 2015); and improvements in subsequent performance (Cockburn, Bell & Stevenson, 2013; Rankin et al., 2015).

Focussing on EIMD attenuation, a volume of 500 mL (Cockburn, Robson-Ansley, Hayes & Stevenson, 2012) of low-fat milk has been demonstrated post-exercise (Cockburn, Stevenson, Hayes, Robson-Ansley & Howatson, 2010) as more effective for attenuating EIMD in comparison to water or a commercially-available sports drink (Cockburn et al., 2008). This series of studies extended to show improvements in aspects of subsequent performance among males (Cockburn et al., 2013); and females (Rankin et al., 2015). However, no such studies to date have been conducted among adolescent athletes and, given their unique nutritional requirements during this stage of rapid development (Desbrow et al., 2014); extrapolation of existing findings among adults to the younger player cannot be assumed.

Establishing a similar role for milk – a widely available, natural and calcium-rich beverage (European Milk Forum [EMF], 2014) among this younger cohort is particularly relevant given their: higher calcium requirements (Institute of Medicine [IOM], 2011; Purcell et al., 2013; Department of Health/Health Service Executive

[DOH/HSE], 2012) ; high prevalence of calcium insufficiencies (Irish Universities Nutrition Alliance [IUNA], 2008); and the recommendation to refrain from using recovery supplements below the age of 18 years (Thomas et al., 2016; Desbrow et al., 2014; Safefood, 2014; Irish Rugby Football Union [IRFU], 2013). Growing the research in the area of Gaelic football is also of merit as there is very limited research on the specific nutritional requirements for this sport (Beasley, 2015), despite its popularity (Woods, Tannehill, Quinlan, Moyna & Walsh, 2010) and unique physiological demands (Cullen et al., 2013) .

To begin investigation among this cohort, this current study protocol is modelled on that of the inaugural investigation of milk as an effective recovery option among team sport players (Cockburn et al., 2013). Cockburn et al. (2013) induced muscle damage among players who then consumed either 500 mL of low-fat milk or 500 mL of water (control) and subsequently took part in a series of performance tests following a recovery period. Modifications to this current study included implementation of a cross-over design; EIMD via a field-based training session rather than lab-based isokinetic dynamometry; variations of performance tests dependent on equipment availability; and a shorter recovery period due to limited access to participants.

Given the paucity of studies among adolescent female Gaelic football players, the objective of this current study is to investigate the effectiveness of milk post-exercise on subsequent performance among this underreported age group, gender and sport.

2.4 Methods

2.4.1 Participants and Experimental Design

Following institutional ethical approval (Appendix G), ten healthy competitive female Gaelic football players were included in this study (age 16.5 ± 0.6 years; height 166.4 ± 6.9 cm, body weight 58.2 ± 9.2 kg).

The entire panel (N=15) was provided with an invitation letter (Appendix A) along with an information sheet of the study protocol (Appendix B). Participants completed a health questionnaire before data collection (Appendix C) and all participants, as well as a parent/guardian, provided written consent to take part in the study (Appendix D). Ten participants were suitable for inclusion and available to participate in this study. Those included were in good health, with no milk allergy/intolerance; no current/pre-existing serious injury; not taking medication to relieve muscle soreness or using nutritional supplements in the last six months; and were not pregnant/post-partum. A week prior to the first trial participants attended a familiarisation session to ensure competency of the performance tests on the trial days.

In a randomised, counterbalanced, cross-over design, participants were allocated to receive either 500 mL of 1% fat milk (M) or 500 mL of water (CON). Participants completed a standard morning 45 minute (min) training session in an indoor sports hall and consumed their allocated test drink within ten minutes of finishing. Participants then underwent a 2-h recovery period where they returned to a classroom environment and consumed no food or drink [only water if required, with volume intake recorded in the participant's food and fluid diary (Appendix F)] and had limited physical activity. Post-recovery, participants completed three performance tests: Countermovement jump height (CJH); Drop jump (DJ); and a 20-m sprint (20-m). Following the training session and recovery period, participants completed a visual analogue scale (VAS) to record muscle soreness (Appendix E, adapted from Johnson, 2005).

A month after the first trial (to control for menstrual cycle stage - Armstrong et al., 2012) this protocol was repeated for the second trial, with participants consuming the test beverage they did not consume at the first trial [Fig. 1].

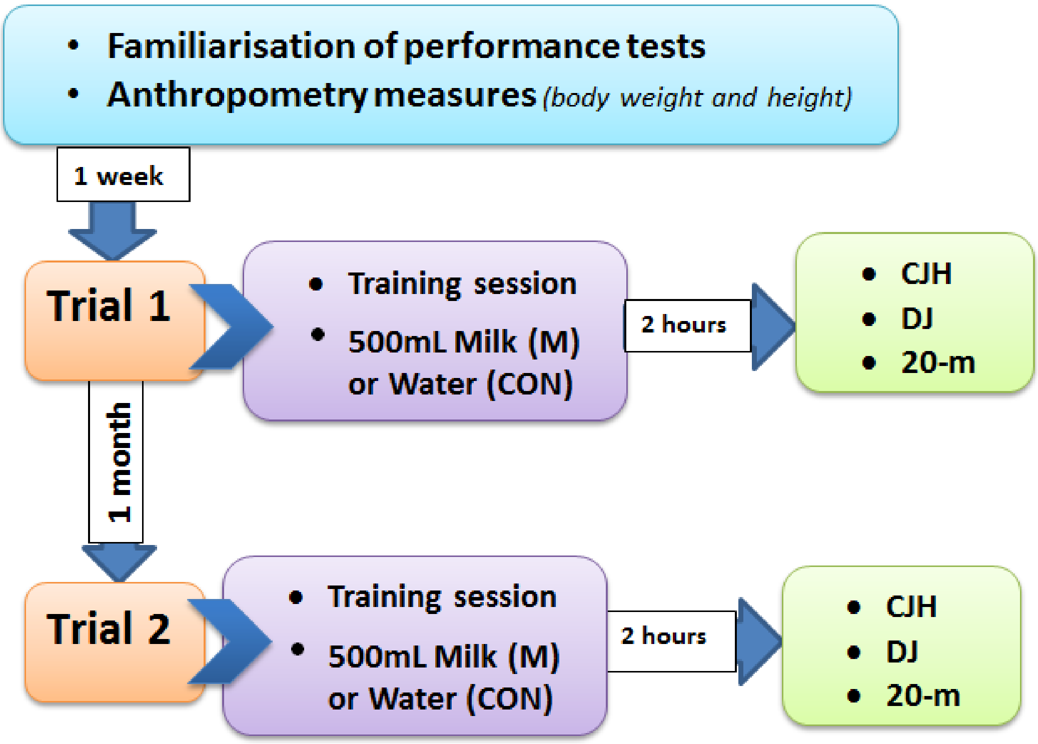

Figure 1: Schematic representation of study protocol "The effect of milk post-exercise on subsequent performance among female Gaelic football players aged 16-18 years"

To control for differences in dietary intakes, participants were instructed to adhere to their habitual diet for the study duration and used a Food and Fluid Diary (Appendix F) to record intakes the day before and morning of each trial; as well as water volume intake during the training sessions and recovery period. Participants were instructed to replicate intakes for each trial, as well as to avoid strenuous physical activity, supplements, caffeine, alcohol, nicotine and anti-inflammatory drugs 48 hours before each trial. Given the month duration prior to the second trial, participants were visited a few days before to re-emphasise these instructions.

To control for differences in training intensities between trials, the team coach facilitated both sessions and was instructed to adhere to the same protocol and in the same sequence (warm-up laps; hand and kick passing drills; solo runs; shooting; core work; sprints; squat jumps; stretching) within the allocated 45-min session.

2.4.2 Drink composition and ingestion schedule

Participants were randomised to receive either 500 mL of 1% fat milk (Avonmore, Glanbia® PLC) or 500 mL of water (Ballygowan, Britvic Ireland® Ltd) [Table II]. A serving of 500 mL was chosen as this milk volume was demonstrated to attenuate muscle soreness following EIMD (Cockburn et al., 2010; Cockburn et al., 2012; Rankin et al., 2015) and decrements in aspects of subsequent performance (Cockburn et al., 2013). It is also considered a volume that is practical to ingest post-exercise (Rankin et al., 2015), as well as being commercially available in 500 mL serving sizes. All test drinks were served in identical plastic cups following overnight refrigeration, stored in cooler bags for the training session duration and consumed within ten minutes of completing the training session.

Table II. Nutrient composition of 500 mL of 1% fat milk (Avonmore, Glanbia® PLC) and 500 mL of water (Ballygowan, Britvic Ireland® Ltd).

	1% Milk (500 mL)	Water (500 mL)
Energy (KJ)	910	0
Energy (Kcals)	215	0
Carbohydrate (g)	25.5	0
Sugars (g)	25	0
Protein (g)	17	0
Fat (g)	5.0	0
Sodium (mg)	220	0.75
Calcium (mg)	625	5.7
Magnesium (mg)	55	0.8
Potassium (mg)	795	0.15
Chloride (mg)	435	1.4

2.4.3 Performance Tests

Countermovement Jump Height (CJH)

CJH is recognised as a fitness attribute among adolescent Gaelic football players (Cullen et al., 2013) as this game often requires the player to jump and catch the ball to obtain posession (Gaelic Athletic Association [GAA], 2015). Using a jump and reach method (VERTEC), participants were required to put their hands on their hips and to flex their lower limbs, immediately launching into a maximal vertical jump to touch the highest height vane possible. A practice jump was conducted and participants performed three jumps interspersed by a 30 second rest, with the best score selected for analysis. To increase motivation the score obtained after each jump was shared with the participant.

Drop jump (DJ)

DJ was tested as it is considered an effective way of enhancing CJH (Marshall & Moran, 2013) and reflects a common Gaelic football manouvre (GAA, 2015). Participants maintained an upright posture with hands on their hips, stepping off a 25 cm height and immediately propelling upwards where jump height was measured (VERTEC). Three trials with a 60 second rest between each were performed, with the best score used for analysis. Again, to increase motivation, the score obtained after each trial was shared with the participant.

20 metre sprint (20-m)

A 20-m sprint has been identified by Cullen et al., (2013) as a performance indicator among adolescent Gaelic football players. Following a 5-minute warm-up three sprint trials were performed, with times recorded to the nearest second (Brower; Wireless Sprint System, USA). Each sprint was separated by a three minute recovery period, with the time obtained after each sprint shared with the participant to increase motivation.

Muscle Soreness

Following the training session and 2-h recovery, participants indicated subjective feelings of muscle soreness on a 1,000 mm VAS (Appendix E, adapted from Johnson, 2005).

2.5 Statistical analysis

All data was analysed using SPSS 22.0 (SPSS, Inc). Data was checked for normality of distribution using the Shapiro-Wilk test. Given the repeated measures design (CJH, DJ, 20-m, VAS) under two different conditions (M, CON), paired t-tests were conducted (Morris, 2013), with a p-value of 0.05 considered significant and data presented as mean and standard deviation (SD).

2.6 Results

Although CJH was slightly higher in the milk group, no significant difference was demonstrated between M and CON for: CJH (35.7 ± 8.5 cm; 34.9 ± 5.3 cm, respectively; p=0.603); or DJ (36.4 ± 7.9 cm; 36.4 ± 5.1 cm, respectively; p=0.971) [Fig 2.].

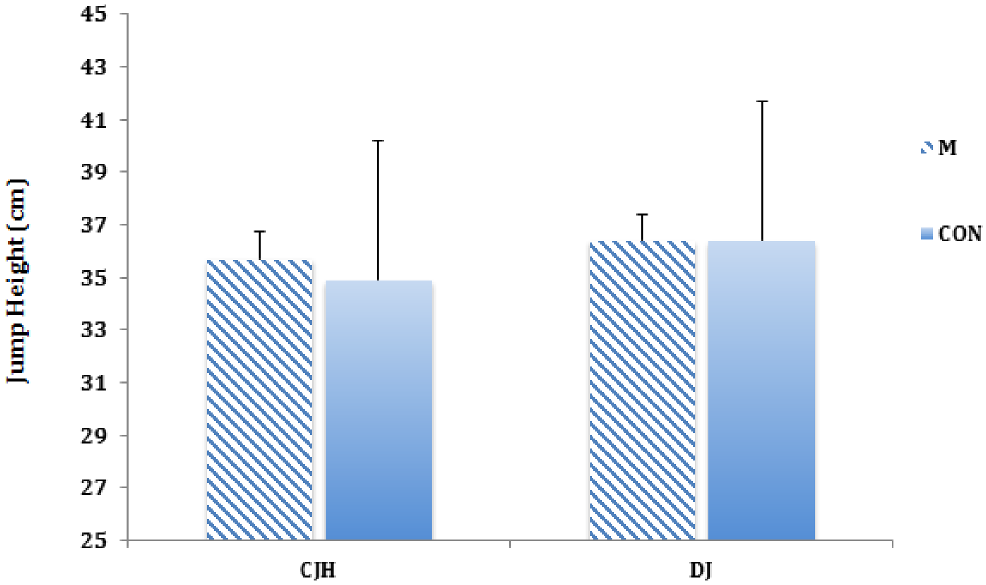

Figure 2: Countermovement Jump Height and Drop Jump (cm) for M and CON groups. Values are presented as mean ± SD.

A significant (p=0.02) difference for 20-m sprint speed was reported between M (3.85 ± 0.35 s) and CON (4.02 ± 0.32 s) [Fig. 3].

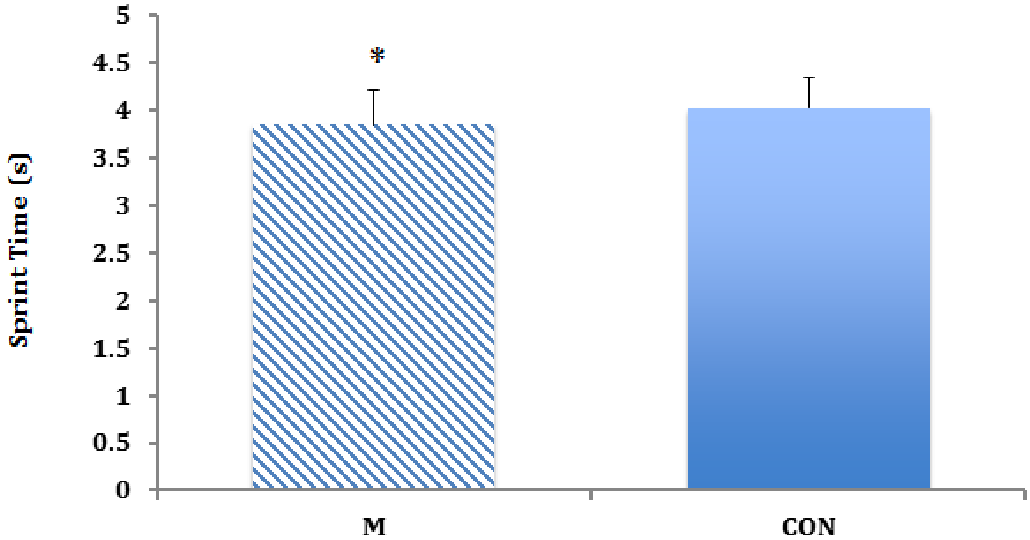

Figure 3: 20-m Sprint Time (s) for Milk and CON groups. Values are presented as mean ± SD. * P<0.05 M vs. CON.

No significant (p=0.3) difference was reported for muscle soreness between CON (2.8 ± 1.2) and M (2.3 ± 1.1) post-recovery [Fig. 4].

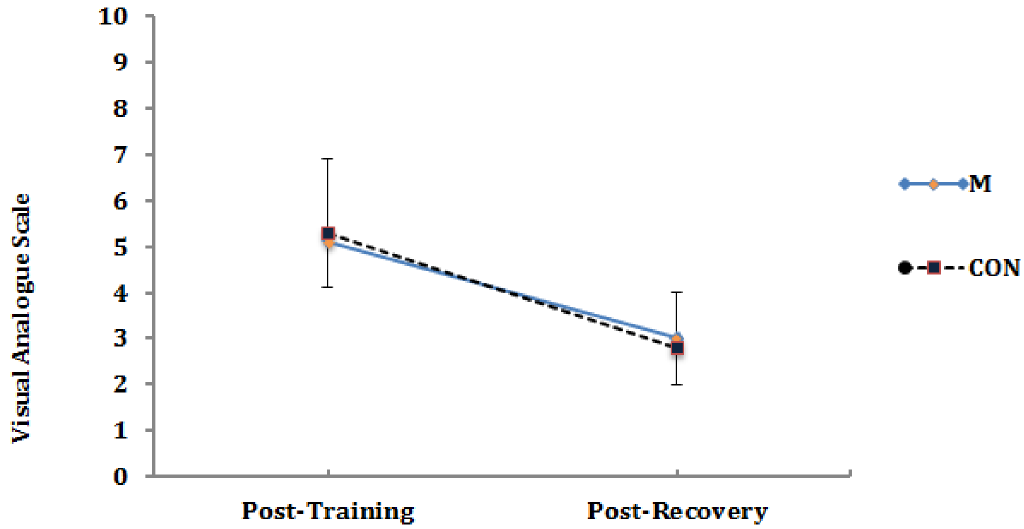

Figure 4: Muscle Soreness Rating Post-training and Post-Recovery for M and CON groups. Values are presented as mean ± SD.

2.7 Discussion

This study supports and expands existing research to an unreported cohort by demonstrating milk as an effective recovery drink post-exercise for subsequent sprint performance among female Gaelic football players aged 16-18 years.

This finding is relevant, as Irish females aged 13-17 years have the highest calcium insufficiencies of the population at 42% (IUNA, 2008), but are also the age group with the highest calcium requirements (IOM, 2011; Purcell et al., 2013). Establishing milk – a calcium-rich beverage (Finglas et al., 2015) – as an effective recovery option helps identify a consumption occasion to assist compliance with the recommended daily 5 servings from the 'milk, yogurt and cheese' food group for this cohort. With a serving of milk equating to 200 mL (DOH/HSE, 2012), 500 mL post-exercise would provide half (2.5) of their daily requirements. Therefore, this finding is not only beneficial for post-exercise recovery but could also assist to help alleviate this calcium shortfall among this cohort and assist compliance with healthy eating guidelines.

As suggested across the existing research, the proposed mechanism for the superior sprint performance observed is likely attributed to milk's natural nutritional composition in addressing the main priorities of post-exercise recovery (Roy, 2008; Sousa et al., 2014).

Endurance exercise elicits muscle protein catabolism and depletion of energy stores (Kammer et al., 2009), with optimal refuelling of glycogen; adequate muscle repair; and restoration of fluid balance main considerations to address post-exercise (Mujika & Burke, 2010; Pritchett et al., 2011; Desbrow et al., 2014; Sawka et al. 2007). Gaelic football is an intermittent, technical and skilful team sport, involving a blend of anaerobic activity for short, high-intensity bouts of activity as well as light to moderate aerobic activity (Mujika & Burke, 2010; Reilly & Doran, 2001; Cullen et al., 2013). Muscle protein breakdown and muscle protein synthesis (MPS) are both stimulated in response to exercise (Maughan & Sherriffs, 2012); however, as the eccentric nature of team sports such as Gaelic football favours protein breakdown over synthesis, this can result in muscle damage (Poortmans, Carpentier, Pereira-Lancha & Lancha, 2012; Maughan & Sherriffs, 2012) and compromised performance (Poortmans et al., 2012; Maughan & Sherriffs, 2012).

Bovine milk's natural composition addresses key post-exercise nutritional considerations by providing the disaccharide lactose to support glycogen resynthesis; whey protein and BCAAs, including leucine, to stimulate MPS; and electrolytes in a fluid form (approximately 90% water) to support rehydration (Roy, 2008; NDC. FHI, 2015a; Fox et al., 2015; Devries & Phillips, 2015; Finglas et al., 2015; Shirreffs, Watson & Maughan, 2007).

The research on milk and muscle recovery evolved from the recognition that co-ingestion of carbohydrate and protein is beneficial for attenuating muscle damage (Saunders, Kane & Todd, 2004; Valentine, Saunders, Todd & St Laurent, 2008) and for improvements in subsequent performance (Saunders et al., 2004; Berardi, Noreen & Lemon, 2008; Betts, Williams, Duffy & Gunner, 2007). Carbohydrate provides a glucose source to replenish glycogen stores, as well as stimulating insulin production which, in turn, promotes amino acid (AA) uptake by muscles (Betts & Williams, 2010; Pritchett et al., 2011; AIS, 2014); with protein supplying the AAs needed to regenerate muscles following intense exercise (Devries & Phillips, 2015).

The 500 mL volume of milk in this study provided 25.5 g of carbohydrate (lactose) to each player (Table I), irrespective of individual body weight. However, based on the recommendation to consume 0.8 g.kg-1.hr-1 carbohydrate (with 0.2-0.4 g.kg-1.hr-1 protein co-ingestion) (Cermak & Van Loon, 2013; Betts & Williams, 2010; Beelen et al., 2010) and that the average body weight of the participants was 58.2 ± 9.2 kg; between 49-67 g of carbohydrate should have been provided to meet this guideline. This shortfall may have resulted in no improvements observed for CJH and DJ and the relatively acute difference in sprint time between the M and W groups. To help address this carbohydrate shortfall in future studies, milk with cereal (Kammer et al., 2009) or chocolate milk (Pritchett & Pritchett, 2012; Ferguson-Stegall et al., 2011; Lunn et al., 2012) may be considered - as both applications have been demonstrated in the literature as effective recovery options due to their favourable carbohydrate to protein ratios.

Consuming protein post-exercise is necessary to supply AAs for insulin-signalling and to stimulate the critical mTOR pathway needed to achieve net protein accretion (Pasiakos, Lieberman, & Mclellan, 2014; Cermak, Res, de Groot, Saris & Van Loon, 2012; Kammer et al., 2009; Blomstrand, Eliasson, Karlsson & Kohnke, 2006). Milk protein consists of 80% casein and 20% whey (Fox, Uniacke-Lowe, McSweeney, & O'Mahony, 2015; Bendtsen et al., 2013)**,** with whey protein a valuable source of BCAAs and the AA leucine for efficient MPS (Salinas-García et al., 2014; Ra et al., 2013; Kainulainen, Hulmi & Kujala, 2013; Devries & Phillips, 2015). The 500 mL of milk consumed in this study provided 17 g of protein which is in line with the recommendation to achieve 15-25 g post-exercise from high-quality protein sources, particularly milk/whey (Beelen et al., 2010; Poortmans et al., 2012; Colombani & Mettler, 2011; Pritchett et al., 2011; Philips, Barr & Lewis, 2011). Based on the requirements of 0.2-0.4 g.kg-1.hr-1 protein (with 0.8 g.kg-1.hr-1 carbohydrate co-ingestion) (Cermak & Van Loon, 2013; Betts & Williams, 2010; Beelen et al., 2012); 15-20 g is recommended; with some participants therefore potentially falling short of optimal requirements, which may have affected the degree of performance improvements observed. However, essential to consider is that there is a paucity of research on specific post-exercise nutrient requirements for the adolescent athlete and, given their unique nutritional requirements (Desbrow et al., 2014; Food Safety Authority of Ireland [FSAI], 2011), research is needed to decipher if these carbohydrate and protein guidelines are relevant for extrapolation and application to this younger cohort of athletes.

As outlined, the rationale for milk's attenuation of EIMD and subsequent performance has focused on its natural provision of carbohydrate and protein. However, given that inflammation of skeletal muscle is associated with EIMD, (Bessa et al., 2016; Tidball, 2005; Schoenfeld, 2012) cellular and molecular responses - including the potential anti-inflammatory components of milk such as lactoferrin and conjugated linoleic acid [CLA] (NDC. FHI, 2013)- also warrant investigation as potential mechanisms. Additionally, the 'dairy matrix' is an emerging theory of research which focuses on the interplay of the entire nutrient portfolio and its synergistic effects, rather than the effect of individual nutrients (NDC. FHI, 2015b; EMF, 2014; Praagman et al., 2016). Milk uniquely provides the sugar lactose; whey and casein proteins; and over 400 different fatty acids (Fox et al., 2015; Parodi, 2004); as well as important vitamins and minerals such as calcium, iodine, phosphorus, potassium, vitamin B2 and vitamin B12 (Finglas, et al., 2015; FSAI 2014; European Commission, 2015). Research into the 'milk matrix' effect in relation to performance nutrition is therefore needed to determine any mechanistic role for the recovery benefits of milk observed across the literature.

EIMD causes small tears to muscle fibres and can result in delayed-onset muscle soreness [DOMS] (Hough, 1902); which can adversely affect performance (Etson, Byrne & Twist, 2003; Twist & Eston, 2005). The research into milk for EIMD attenuation (Sousa et al., 2014) has demonstrated a volume of 500 mL (Cockburn et al., 2012) of semi-skimmed milk post-exercise (Cockburn et al., 2010) as more effective in attenuating EIMD in comparison to water or CE (Cockburn et al., 2008). Cockburn et al. (2013) expanded the research to the team-sport player; with male soccer players receiving either 500 mL of milk or water following muscle damage and performance indicators measured prior and at 24, 48 and 72 post-exercise. This current study protocol is modelled on this inaugural study by Cockburn et al. (2013). However, modifications to this current study were applied and include: implementation of female, competitive, adolescent athletes; a focus on Gaelic football; a cross-over design; EIMD via a field-based training session; variations of performance tests; and a shorter recovery period.

With the playing level of participants competitive rather than elite, such allows extrapolation of findings to a larger cohort of players. Inclusion of adolescent female participants is also welcome as studies in sports science, recovery nutrition and Gaelic football are typically biased towards adult male athletes (Costello, Bieuzen & Bleakley, 2014; Pritchett et al., 2011; Beasley, 2015). Despite the popularity of Gaelic football among adolescents in Ireland (Woods et al.,2010) and its unique physiological demands (Cullen et al., 2013), very little research exists on the nutritional requirements for this sport, with recommendations applied from other team sports (Beasley, 2015). This study, therefore, assists to expand research into appropriate nutritional recovery strategies for an underreported gender, cohort and sport.

Unlike Cockburn et al. (2013) which implemented an independent study design, the cross-over, counter-balanced design of this current study allowed each participant to act as their own control and, in turn, discount any individual variances that could influence results (Elbourne et al., 2002). The protocol also encompassed elements of ecological validity: EIMD was induced by a typical field-based training session rather than isokinetic dynamometry; the milk type chosen was commercially and widely available, as well as being compliant with Irish dietary guidelines (DOH/HSE, 2012); and the milk type and brand (Avonmore L1%ght Milk, Glanbia® PLC) was conveniently available in packaged volumes of 500 mL – a volume considered practical to consume post-exercise (Rankin et al., 2015).

Although performance indicators were chosen to reflect physical demands associated with Gaelic football (GAA, 2015), performance should ideally be assessed via match performance, as this is where any ergogenic effect of a nutritional intervention would be most valuable. Cockburn et al., (2013) addressed this, with players taking part in the

Loughborough Intermittent Shuttle Test (LIST) at 72h to reflect the physiological demands of soccer (Nicholas, Nuttall & Williams, 2000). Therefore, the development of a validated performance test specific for Gaelic football is required to determine any valuable performance improvements to players of this specific sport and should be considered for future research. Additionally, performance indicators should be repeated at 24 h 48 h and 72 h as per Cockburn et al. (2013) and Rankin et al. (2015), which is reflective of performance demands of team sport players. The 2-h recovery time applied in this study is not reflective of the demands of Gaelic football as it is uncommon that a player would be required to perform again within this short time frame. Additionally, it is also questioned whether 2-h is sufficient for the complete digestion of milk (Pritchett et al., 2009). However, this recovery duration was chosen due to: limitations of participant and facility access; to minimise student absence from class and fasting duration; and to optimise control over food, fluid and activity during recovery.

Despite descrepencies in the study protocols outlined above, the objetive of investigating milk as an effective recovery option for improvements in subsequent team sport performance was similar for this study and that of Cockburn et al. (2013). Similar to findings of this study, Cockburn et al. (2013) reported no difference in CJH between M and W; but sprint time was improved- with mean time for 15 m LIST sprint at 72 h significantly ($p=0.009$) less in M (0.0% ± 2.0%) compared to W (2.4% ± 1.9%).

Across both of these studies, it could be postulated that the improvement in sprint performance may have been solely due to the caloric content of milk, rather than nutrient provision i.e. carbohydrate or protein (Thomas, Morris & Stevenson, 2009). The test drinks provided were isovolumetric milk and water; and not matched for caloric or carbohydrate provision. Comparison of isocaloric test beverages has strongly been advocated by Pritchett et al. (2011) when assessing the effectiveness of recovery options, as was implemented by Rankin et al. (2015). Additionally, given the distinct taste, texture and colour of milk, it was not possible to blind participants from the test drink they were receiving and, therefore, it cannot be discounted that a placebo effect of perceiving milk as an ergogenic drink may have contributed to the increased sprint performance observed in the milk group.

Rankin et al. (2015) applied a more robust test beverage protocol which compared milk with an isocaloric carbohydrate solution to investigate the attenuation of EIMD among and between male and female adults. A significant ($p<0.05$) increase in peak torque was reported for the milk group between baseline and 24 h (-5.3 ± 15.9%; -12.0 ± 11.4% respectively); with a likely benefit among females for 20-m sprint between baseline and 72 h (0.0 ± 3.0%; 2.7 ± 3.6 %, respectively). The authors note the contradictory effects of EIMD among females reported in the literature (Sayers & Clarkson, 2001; Hubal, Rubinstein & Clarkson, 2008); and attribute the beneficial effects observed among females compared to males to the proposed protective effect of oestrogen in attenuating EIMD (Markofski & Braun, 2014). As this current study also resulted in an improved 20-m sprint time in the milk group, it could be postulated that oestrogen may have played a role; although further research is needed to establish the mechanistic effects and any gender differences among adolescent athletes.

Considering that adequate hydration positively affects performance (Maughan & Sherriffs, 2012); and that isovolumetric test drinks were provided in this current study (with additional fluid intakes controlled for), the improved sprint time observed may have been influenced by superior fluid restoration over the 2-h recovery in M compared with W. Milk's rehydrating properties post-exercise have been reported in the literature, with participants remaining euhydrated during a 4-h recovery period following skimmed milk consumption compared to water or a commercially available carbohydrate-electrolyte (CE) drink (Shirreffs et al., 2007). The mechanism of milk's effective rehydration has been attributed to the natural provision of fluid and electrolytes; as well as its protein and energy content which delay the gastric emptying of milk, slowing down its entry into circulation and preventing diuresis stimulation (Shirreffs et al., 2007; Volterman et al., 2014; Watson, Love, Maughan & Shirreffs, 2008; James, Clayton & Evans, 2011; Desbrow et al., 2014; Seery, 2015). Relevant to the younger athlete, Volterman et al. (2014) showed that among youths (7-11 years and 14-17 years), a significantly ($p<0.01$) higher percentage of skimmed milk (74% ± 18%) was retained over a 2-h recovery compared with water (47% ± 26%). However, in this current study limited access to participants did not allow for the investigation of beverage retention (e.g. urine volume output), meaning the potential effect of milk's rehydrating benefits for the improved sprint performance observed cannot be discounted.

An additional weakness of this study design is the omission of baseline performance recordings which would have given a clearer indication of milk's potential beneficial effects. However, the absence of these recordings is somewhat offset by the study design: the counter-balanced, repeated measures design discounted any order effect; the cross-over nature allowed participants to act as their own control; and the familiarisation day allowed competence in performance protocols to be established prior to the start of the study.

Recognised also is that, as exercise intensity impacts the degree of muscle damage induced (Heavens et al., 2014), assessing individual $\dot{V}O_2$max and tailoring the training sessions to ensure work performed was at a certain percentage of individual $\dot{V}O_2$max would have been more robust than applying a general intensity (Mann, Lamberts & Lambert, 2013). Previous studies have also used blood markers of muscle damage – mainly creatine kinase (CK) and myoglobin (Mb) – to assess EIMD. Although CK and Mb are considered qualitative indicators of damage with large variability (Clarkson & Hubal, 2002; Baird, Graham, Baker & Bickerstaff, 2012), these readings may have been of benefit in this current study to indicate muscle recovery as well as establishing if the training session protocol was of an appropriate intensity to elicit muscle damage. However, due to equipment and participant restrictions this could not be facilitated; with the team coach conducting both training sessions and following the same protocol, pattern and time allocation to ensure consistency across both trials.

Research studies with a larger sample size across a range of sports and competitive levels are warranted to establish milk as an effective recovery beverage among female adolescents. Low-fat milk was chosen as it is the milk type used in similar studies investigating muscle recovery (Cockburn et al., 2008; 2010; 2012; 2013; Rankin et al., 2015), as well as being the recommended milk type in the Irish dietary guidelines for this population group (DOH/HSE, 2012). However, the effectiveness of other commercial milks (whole, skimmed, chocolate, protein milk) could also be investigated; as well as specifically formulated commercially-available recovery drinks. Expansion to compare milk with commonly consumed post-exercise beverages is also required as, if adhering to recovery nutrition guidelines; players should ingest an energy, fluid and nutrient source following intense exercise (Desbrow et al., 2014). For example, CE beverages are a growing industry (Committee on Nutrition and the Council on Sports Medicine and Fitness [CNCSMF], 2011) and a popular choice post-exercise among adolescent athletes (Walsh et al., 2011). Establishing milk as a more effective recovery option to displace such commercial CE solutions would be beneficial as excessive consumption of CE drinks has been associated with excess caloric intakes, weight gain and dental erosion (CNCSMF, 2011; Lamarche et al., 2016).

Investigation among male adolescents is additionally warranted as these are also under-reported in the literature and are more likely than females to be attracted towards sports supplements (McDowall, 2007), particularly protein supplements (Walsh et al., 2011). This is noteworthy as the use of sports supplements in those under 18 years of age is not advised due to the lack of research of their effects on the developing body, with nutritional needs advised to be met through natural food sources (Thomas et al., 2016; Desbrow et al., 2014; Safefood, 2014; IRFU, 2013). Establishing milk, a natural source of high quality protein (EMF, 2014), as an effective option post-sport could also encourage compliance with these these guidelines.

2.8 Conclusion

This study demonstrates a role for milk – a natural, accessible, affordable and calcium-rich beverage (EMF, 2014) – post-exercise among female Gaelic football players aged 16-18 years for improving subsequent sprint performance. This finding expands on existing research by investigating milk's recovery properties among an unreported age group (Desbrow et al., 2014); an underreported gender (Costello et al., 2014); and an underreported sport (Beasley, 2015).

Future studies should include larger sample sizes, with expansion to: explore potential roles among male adolescent athletes; compare effectiveness with popular post-exercise recovery options; and investigate applications across a variety of sports and competitive levels.

2.9 Conflict of Interest

The author wishes to declare that this research project was funded by the employer of the author – The National Dairy Council, Ireland – which is a non-profit organisation funded by a voluntary levy contribution by Irish dairy farmers. By funding this research, the intention of the NDC was for their employer to fulfil their Masters degree and this funding did not influence the research outcomes in any way.

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Appendix A: Letter of Invitation

University of Chester

I am seeking participants for a Research Project entitled:

"The effect of milk post-exercise on subsequent performance among female Gaelic football players aged 16-18 years"

Project:

Effective recovery following intense exercise is necessary to ensure performance is not compromised during subsequent training sessions/matches.

Milk is a natural source of a number of nutrients and has been indicated as a potentially effective recovery drink post-exercise.

This study seeks to investigate the effectiveness of milk after exercise on subsequent performance compared to a control drink (water) among female Gaelic football players aged 16-18 years.

Who are we looking for?

Females aged 16-18 years, who are currently on the female Gaelic football panel at Maynooth Post-Primary School.

Where will the study take place?

This study will take place on the sports pitch owned by Maynooth Post-Primary School and in the sports hall of the school.

If interested please:

- Read the information enclosed with further details
- Complete the short health questionnaire and consent forms (ensuring to include guardian consent).
- Return these to your coach, ideally at your next training session.

For further information, or if you have any queries, please do not hesitate to contact me.

Regards,

Caroline O'Donovan BSc *RNutr (Food)*

Email: 1426890@chester.ac.uk

Appendix B: Participant information sheet

"The Effect of Milk Post-Exercise on Subsequent Performance Among Female Gaelic Football Players Aged 16-18 Years"

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the study?

Effective recovery following intense exercise is necessary to ensure performance is not compromised during subsequent training sessions/matches. Milk is a natural source of a number of nutrients and has been indicated as a potentially effective recovery drink post-exercise. This study seeks to investigate the effectiveness of milk after exercise on subsequent performance among female Gaelic football players aged 16-18 years.

What will you have to do?

You will be asked to: maintain your normal diet during the study duration; have the same evening meal and breakfast before training sessions; avoid strenuous physical activity in the 48 hours before the test days; avoid supplements, caffeine, alcohol, nicotine and anti-inflammatory drugs 48h before the test days.

You will attend one of your standard morning training sessions, instructed by your coach. After which you will receive either 500 mL of milk (plain, 1% fat) or 500 mL of water. You will return to class for two hours, refraining from food and drink intake, apart from water. You will then complete simple performance tests including: jump height; drop jump and a 20-meter sprint. You will also be asked to rate your muscle soreness on a scale at various time points. These performance measures will require absence from one class (1 hour).

Familiarisation Day

- Height and body weight measures taken
- Performance tests in the order they will be conducted on test days
- Explanation of muscle soreness scale
- Instructions for the trial period explained

Test Day 1

- Standard training session (morning)
- Milk/Water consumption
- 2 hour recovery in classroom
- Performance tests

Test Day 2

- *1 month later : complete the* same protocol as the first test day but receive the drink you did not receive on test day

Why have I been chosen?
You have been chosen because you are a female Gaelic football player on the panel of the senior team in Maynooth Post-Primary School.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form (enclosed with this information). If you decide to take part you are still free to withdraw at any time and without giving a reason, which will be dealt with in a supportive and confidential manner. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What are the possible disadvantages and risks of taking part?
There are no disadvantages or risks foreseen in taking part in the study. Muscle soreness, fatigue, hunger post-training and the risk of injury are possibilities as a result of taking part in this study. However, these risks are no greater than that which might result from a typical training session.

What are the possible benefits of taking part?
By taking part, you will be contributing to the development of research into effective recovery strategies for sports performance. You will also gain insight into a research project protocol at Masters level.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact the Dean of the Faculty of Life Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 0044 1244 513055.

Will my taking part in the study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?
The results will be written up into a dissertation for my final project of my Masters in 'Exercise and Nutrition Science'. Individuals who participate will not be identified in any subsequent report or publication.

Who is organising the research?
The research is conducted as part of an MSc in Exercise & Nutrition Science within the Department of Clinical Sciences & Nutrition at the University of Chester. The study is organised with supervision from the department by Caroline O'Donovan, an MSc student.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please do not hesitate to contact: Caroline O'Donovan *RNutr(Food) BSc* 1426890@chester.ac.uk

Appendix C: Health Screening Questionnaire

"The effect of milk post-exercise on subsequent performance among female Gaelic football players aged 16-18 years"

Researcher: *Caroline O'Donovan BSc RNutr(Food)*

Name: ________________________________

Contact number: ___________________________ Date of birth: ______________

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1. Do you have an allergy to milk or intolerance to dairy or lactose products? YES/NO
2. Do you have a known coronary (heart) disease? YES/NO
3. Do you have an uncontrolled metabolic disorder or a respiratory disease? YES/NO
4. Are you taking any medication to relieve pain or reduce inflammation? YES/NO
5. Do you have any current or pre-existing serious injury that may affect your ability to take part in the training session and performance test? YES/NO
6. Are you currently taking nutritional supplements, or have taken nutritional supplements in the last 6 months? YES/NO
7. Are you pregnant, or have you been pregnant in the last six months? YES/NO
8. Do you know of any other reason why you should not participate in physical activity? YES/NO

Thank you for taking your time to fill in this form. If you have answered 'yes' to any of the above questions, unfortunately you will not be able to participate in this study.

Appendix D: Consent Form

Title of Project:

"The effect of milk post-exercise on subsequent performance among female Gaelic football players aged 16-18 years"

Name of Researcher: Caroline O'Donovan BSc RNutr (*Food*)

Please initial box

I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐

I agree to take part in the above study. ☐

______________________	______________	______________________
Name of Participant (Block capitals)	Date	Signature
______________________	______________	______________________
Name of Parent/Guardian (Block capitals)	Date	Signature
______________________	______________	______________________
Researcher (Block capitals)	Date	Signature

(Please complete the two forms provided and return to the researcher)

Appendix E: VAS

Numeric Pain Scale

Please indicate your feeling of muscle soreness on the scale below:

0	1	2	3	4	5	6	7	8	9	10
No pain										Most pain

Appendix F: Food & Fluid Diary

To ensure results are as accurate as possible, it is necessary to consume the same food and fluid the day before both test days; the morning of the test days; during training; and throughout the recovery period.

As test days are a month apart, recording intake will assist you in remembering your exact intake.

Please record intakes around the first test day and repeat this intake around the second test day as accurately as possible.

Remember…

- Do not write down what you think the researchers would want to see. All information is confidential and no person's diet will be "judged" by the researchers.
- All food & fluid intake should be recorded on the food & fluid diary. All medications/ vitamin & mineral supplements should also be recorded on the Food & Fluid Diary.
- Include as much detail so that you can replicate intakes accurately and easily.
- Time: Try and replicate the timing of the meals and snacks.
- Ingredients: In this column you should list the ingredients of a particular meal.

E.g. 1: Bowl of porridge: the ingredients that should be listed here are – porridge oats, milk (type) and anything added e.g. honey/ blueberries/ seeds etc.

E.g. 2: Chicken stir fry example: the ingredients that should be listed individually here are e.g. chicken fillet, red pepper, mange tout, carrots, noodles and olive oil.

- Amount: If the food does not come in a portion e.g. rice/pasta/cereal, weighing these items is best if possible.
- Brand Name: Record the brand name of products where applicable.
- Test Drink: Note that on the second test day you will receive the test drink you did not receive on the first test day.
- Note: only water is allowed during training and recovery period but please record volume and brand.
- Use the following example as a guide to filling in the Food Diary. Please note that this is an example and you should accurately report the typical foods and amounts you have consumed.

Food & Fluid Intake – Sample Food Diary

Meal	Time	Ingredients	Amount mls/grams/portion(s)	Brand Name
		Day Before Test Day		
Breakfast	8am	Porridge Milk Honey Toast –wholemeal Butter Orange Juice (no bits)	40g 100mL 1 teaspoon 9 slices 1 pat (7g) 1 glass (200ml)	Flahavans Avonmore Light Boyne Valley Brennans Kerrygold Tropicana
Lunch	1pm	Bread (wholemeal) Butter Ham Cheese Yogurt Drink – strawberry Apple	9 slices 1 pat (7g) 1 slice 25g/1 slice 200mL 1 medium size	Brennans Kerrygold Brady's Dubliner Yop Granny Smith
Dinner	6pm	Chicken Fillet Red Pepper Mange Tout Carrot Noodles Olive Oil Milk	90g one quarter (medium) 5 1 medium 9 nests -100g 9 sprays 200ml glass	Coyne's Butchers Tesco Vegetables Tesco Vegetables Tesco Vegetables Blue Dragon Frylight Spray Avonmore Light
Snacks	11am	Banana	1	Fyffes

		Mixed nuts (unsalted)	40g	Tesco own brand
	4pm	Potato Waffles	2	Birdseye
		Ketchup	10g	Heinz
		Biscuits – Hobnobs	2	McVitties
	8pm	Tea with	Cup (200mL)	Lyons
		Milk	20mL	Avonmore Light
		Test Day		
Breakfast				
	6.30am	Porridge with	40g	Flahavans
		Milk	100mL	Avonmore Light
		Honey	1 teaspoon	Boyne Valley
		Toast	9 slices	Brennans
		Butter	1 pat (7g)	Kerrygold
		Orange juice (no bits)	1 glass (200ml)	Tropicana
Snacks	7.45am	Banana	1	Fyffes
During Training	8-9am	Water	500mL	Ballygowan
After Training			Milk	
During Recovery	9-11am	Water	1,000mL	Ballygowan

Food & Fluid Intake: Test Day 1

Meal	**Time**	**Ingredients**	**Amount** mls/ grams/ portion(s)	**Brand Name**
		Day Before Test Day		
Breakfast				
Lunch				
Dinner				
Snacks				
		Test Day		
Breakfast				
Snacks				
Water volume during Training		Water		
After Training				
Water volume during Recovery		Water		

Food & Fluid Intake: Test Day 2

Meal	**Time**	**Ingredients**	**Amount** mls/ grams/ portion(s)	**Brand Name**
		Day Before Test Day		
Breakfast				
Lunch				
Dinner				
Snacks				
		Test Day		
Breakfast				
Snacks				
Water volume during Training		Water		
After Training				
Water volume during Recovery		Water		

Appendix G: Faculty of Life Sciences Research Ethics Committee Approval

Faculty of Medicine, Dentistry and Clinical Sciences

Research Ethics Committee

frec@chester.ac.uk

26/10/2015

Caroline O'Donovan

Silken Gardens

Dublin Road

Maynooth

Dear Caroline

Study title: ***The effect of milk post exercise in subsequent performance among female Gaelic football players aged 16-18 years***

FREC reference: ***1126/15/CO/CSN***

Version number: ***1***

Thank you for sending your application to the Faculty of Life Sciences Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, provided that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	September 2015
Appendix A – List of References	1	September 2015
Appendix B – Summary CV for Lead Researcher	1	September 2015

Appendix C – Letter(s) of invitation to participants	1	September 2015
Appendix D – Participant Information Sheet [PIS]	1	September 2015
Appendix E – Participant Consent Form	1	September 2015
Appendix F – Written permissions from relevant personnel	1	September 2015
Appendix G – Summary CV for assistant	1	September 2015
Appendix H – Health Questionnaire	1	September 2015
Appendix I – Garda vetting approval	1	September 2015
Appendix J – Food Diary record	1	September 2015
Appendix K – Letter of sponsorship confirmation	1	September 2015
Appendix L – Numeric pain scale	1	September 2015
Response to FREC request for further information or clarification	1	September 2015

Please note that this approval is given in accordance with the requirements of English law only. For research taking place wholly or partly within other jurisdictions (including Wales, Scotland and Northern Ireland), you should seek further advice from the Committee Chair / Secretary or the Research and Knowledge Transfer Office and may need additional approval from the appropriate agencies in the country (or countries) in which the research will take place.

With the Committee's best wishes for the success of this project.

Yours sincerely,

Simon Alford

Chair, Faculty Research Ethics Committee

Enclosures: Standard conditions of approval.

Cc. Supervisor/FREC Representative

Appendix H: Permission from Maynooth Post primary School

etb

kwetb

Maynooth Education Campus

Moyglare Road,
Maynooth,
Co. Kildare.

To whom it concerns,

It is with great pleasure that we grant Caroline O' Donovan permission to conduct her research project on the grounds of Maynooth Education Campus during the academic year 2015-2016.

Caroline has also been granted permission to recruit members of the Maynooth Post Primary School's female Gaelic football panel as participants as she sees fit.

If you require any further clarification or information please do not hesitate to contact me.

Yours sincerely,

Brendan Broderick

Deputy Principal
Maynooth Post Primary School
01-6286060

Sean Aghas
Priomh Oifigeach Feidhmiúcháin

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Appendix I: Confirmation of Sponsorship Funding

THE NATIONAL DAIRY COUNCIL

FREC Secretary
Faculty of Life Sciences
Administration Office
Molloy 106
University of Chester
Parkgate Road
Chester
Chesire
CH1 4BJ
United Kingdom

14th July 2015

To Whom It May Concern,

I confirm that the research project of Caroline O'Donovan for the Masters degree in Exercise and Nutrition Science with the University of Chester will be funded by The National Dairy Council (NDC), Ireland. This funding amount will be agreed between the NDC and the lead researcher (Caroline O'Donovan).

Yours Sincerely,

Z. K

Zoë Kavanagh
CEO
The National Dairy Council

Appendix J: Garda Vetting of Lead Researcher Confirmation

Barnardos

Private & Confidential
Ms Caroline O'Donovan
The National Dairy Council
Innovation House,
3 Arkle Road,
Sandyford Industrial Estate,
Dublin 18

Confirmation of Results of Vetting Check.

The following vetting request has been processed and records indicated that there are no disclosures in respect of this applicant.

Name	Address	Date of Birth	Comments
Caroline O'Donovan	Apt 5 Silken Gardens Maynooth Kildare	22/09/86	Form attached

Checks were carried out based on the information supplied on the application form.

Please note that vetting checks alone are not guarantee of child protection but are part of an overall recruitment and selection policy.

Please note this is an important document and should be retained by you as such.

Please also note we do not keep any copies of this document, and so would be unable to provide this document again.

Authorised signatory: ____________ Suzanne Tompkin

Date: 4/6/15

Patron / Éarlamh: Michael D Higgins, President of Ireland / Uachtarán na hÉireann
Chairman / Cathaoirleach: Alan Wyley
Chief Executive / Príomhfheidhmeannach: Fergus Finlay

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Appendix K: Trial Recordings and Participant Information

Trial Recordings

ID	Muscle soreness Pre-recovery (milk)	Muscle soreness Post-recovery (milk)	CJH (milk)	DJ (milk)	20-m (milk)		Muscle soreness Pre-recovery (water)	Muscle soreness Post-recovery (water)	CJH (water)	DJ (water)	20-m (water)
001AH	5	3	33.8	34.8	3.79		5	3	35.8	40.8	3.85
003CJ	4	2	32.2	37.2	3.99		6	4	34.2	38.2	4.07
005RH	6	1	33.2	31.2	3.94		6	3	34.2	38.2	4.44
006RNCB	5	2	32	30	3.77		5	4	31.2	31.2	4.13
007DMCG	6	2	55.6	54.6	3.86		7	4	43	43	3.79
008MH	4	1	30.6	30.6	4.03		3	1	29.6	31.6	4.19
009EC	5	2	25.4	27.4	4.53		2	1	26.4	27.4	4.52
010AW	6	4	31.5	35.5	3.99		6	2	33.5	35.5	3.97
011EMC	6	4	42.1	42.1	3.23		7	4	41.1	42.1	3.51
012KM	4	2	40.3	40.3	3.38		6	2	40.3	36.3	3.7
Mean	5.1	2.3	35.7	36.4	3.85		5.3	2.8	34.9	36.4	4.02
SD	0.9	1.1	8.5	7.9	0.358		1.6	1.2	5.3	5.1	0.319

Participant Information

ID	Age	DOB	Weight (kg)	Height (cm)	Drink (T1)	Drink (T2)	Reach Height (cm)
001AH	15.89	14/01/2000	49	165.6	M	W	212.2
003CJ	17.39	18/07/1998	73	169	M	W	212.8
005RH	16.7	25/03/1999	54	170.7	M	W	212.8
006RNCB	17.42	16/09/1998	53	166.6	M	W	211.8
007DMCG	16.1	01/11/1999	67	169.7	M	W	211
008MH	15.97	18/12/1999	62	161.7	W	M	207.4
009EC	15.53	25/05/2000	57	168.4	W	M	211.6
010AW	16.82	09/02/1999	60	161	W	M	203.5
011EMC	16.81	15/02/1999	42	152.8	W	M	192.9
012KM	16.2	23/09/1999	65	178.5	W	M	224.7
Mean	16.5		58.2	166.4			210.07
SD	0.6		9.2	6.9			8.06

Appendix L: SPSS Output Data

- Countermovement Jump Height; Drop Jump; 20-m Sprint

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Milk CJH (cm)	35.6700	10	8.45682	2.67428
	Water CJH (cm)	34.9300	10	5.28079	1.66993
Pair 2	Milk DJ (cm)	36.3700	10	7.92732	2.50684
	Water DJ (cm)	36.4300	10	5.09663	1.61170
Pair 3	Milk Sprint Time(s)	3.8510	10	.35862	.11341
	Water Sprint (s)	4.0170	10	.31913	.10092

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Milk CJH (cm) & Water CJH (cm)	10	.902	.000
Pair 2	Milk DJ (cm) & Water DJ (cm)	10	.771	.009
Pair 3	Milk Sprint Time(s) & Water Sprint (s)	10	.849	.002

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Milk CJH (cm) - Water CJH (cm)	.74000	4.34516	1.37406	-2.36834	3.84834	.539	9	.603
Pair 2	Milk DJ (cm) - Water DJ (cm)	-.06000	5.15282	1.62946	-3.74611	3.62611	-.037	9	.971
Pair 3	Milk Sprint Time(s) - Water Sprint (s)	-.16600	.19027	.06017	-.30211	-.02989	-2.759	9	.022

- Visual Analogue Scale

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Milk Muscle Soreness Score Pre Recovery	10	4	6	5.10	.876
Water Muscle Soreness Pre Recovery	10	2	7	5.30	1.636
Milk Muscle Soreness Score Post Recovery	10	1	4	2.30	1.059
Water Muscle Soreness post Recovery	10	1	4	2.80	1.229
Valid N (listwise)	10				

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Milk Muscle Soreness Score Pre Recovery - Water Muscle Soreness Pre Recovery	-.200	1.476	.467	-1.256	.856	-.429	9	.678
Pair 2	Milk Muscle Soreness Score Post Recovery - Water Muscle Soreness post Recovery	-.500	1.434	.453	-1.526	.526	-1.103	9	.299
Pair 3	Milk Muscle Soreness Score Pre Recovery - Milk Muscle Soreness Score Post Recovery	2.800	1.033	.327	2.061	3.539	8.573	9	.000
Pair 4	Water Muscle Soreness Pre Recovery - Water Muscle Soreness post Recovery	2.500	1.080	.342	1.727	3.273	7.319	9	.000